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Upcycling Plastic Via Thermal Compression

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UPCYCLING PLASTIC VIA THERMAL COMPRESSION

By

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UPCYCLING PLASTIC VIA THERMAL COMPRESSION

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SENIOR PROJECT ABSTRACT

Each year Americans throw away 35 billion plastic bottles. The goal of our project is to demonstrate an alternative to simply discarding unwanted plastic. Our process shows how plastic bottles can be transformed into coasters by using a blender, mold, and heat press.

We focused on high-density polyethylene (HDPE) since it is readily available and safe to work with. HDPE is often thrown away because it is not always economical to recycle due to its low yield.

Many hours of testing and visits to the fabrication lab taught us about the tribulations of upcycling plastic and the complexities that come with creating a mold for new products. We conducted multiple blending, heating, cooling, pressing, and extracting tests to determine the optimal plastic piece size, press conditions, and mold transferring methods.

Fall semester, we focused on designing a process for collecting and processing plastic while determining ideal operating conditions for the heat press. This spring, we altered old molds, designed new molds, and tested rapid cooling methods.

Our ability to design a process that produces one coaster in approximately 30 minutes using only a heat-press proves that this alternative solution to plastic waste has great potential to be scaled up.

HONORS COMPONENT ABSTRACT

Polypropylene (PP) is a readily available plastic used in many different industries. Unlike HDPE, PP is accepted at most recycling plants. My goal is to determine whether the process that my group designed to create coasters using HDPE and low-density polyethylene (LDPE) can also be used to create coasters out of PP. I planned on mirroring the testing that my group previously completed. Depending on my results, I was going to either update our written instructions to include PP in the process or write a new set of instructions using PP to create coasters.

INTRODUCTION AND BACKGROUND

Senior Project Problem Statement

Polyethylene is the second most commonly used plastic in the world. Polyethylene comes in two forms: high-density polyethylene (HDPE) and low-density polyethylene (LDPE). Both HDPE and LDPE are left to waste because they are not economically viable to recycle due to their typically low yield when being recycled. Our group aims to upcycle this commonly rejected plastic by designing a treatment process to produce coasters and soap dishes via thermo-forming with the aid of a heat press.

Honors Component Problem Statement

Polypropylene (PP) is a thermoplastic polymer with similar characteristics as HDPE and LDPE. PP is a versatile plastic that is used in a wide array of industries, from consumer packaging to medical supplies to athletic apparel. My goal is to either verify that the process that my group designed to create coasters using HDPE and LDPE can also be used to create coasters using PP or to redesign a process to create coasters using PP.

Project Adoption

Our team decided to continue a project started by one of the senior groups last year. The goal of their project was to update and modify a 40-year-old heat press so that it could produce products out of recycled plastic. The original heat press had two platens, two heat sheets, thermocouples attached to the face of each platen, cooling tubes, and a screw press mechanism. The previous group added a temperature controller to eliminate the use of the cooling tubes. They set the controller at 127˚C (roughly 260˚F) to get the plastic (high-density polyethylene) to melt and mold appropriately. They also installed a pneumatic air cylinder to replace the screw press mechanism. Our group focused on designing a process to use the heat press to create coasters from plastic that would otherwise be discarded.

We chose this project for multiple reasons. First, we thought the heat press offered more opportunities than rainwater collection since there are many improvement possibilities as well as molds we could design. Second, Thomas has a lot of fabrication and machining experience which will be helpful when working in the Fabrication Lab. Third, gaining an understanding of the heat pressing process and heat transfer will be a good learning opportunity for the group since most of us are not required to take thermodynamics. Lastly, our group will not have to start from square one with this new project, since the previous group did a decent amount of foundational work.

Senior Project Background Research

To get a better understanding of our project, we decided to split up research tasks based on the main aspects of our project. We decided that the most beneficial topics to research were the compression molding process, molding processes, plastic properties, plastic/material testing, and the environmental impacts concerning recycling plastics (see Appendix).

Lianne researched compression molding in-depth. Her research includes how the compression molding process works, background information on compression molding, an overview of composite materials (thermoset composites and thermoplastics) that are commonly used in compression molding, the four main steps of compression molding for thermoset composites, a description of the three most common types of molds used in compression molding, factors that must be considered for compression molding, and a list of advantages of compression molding. The desired composite is pre-formed into the shape of the mold because it helps improve the performance of the finished part. Therefore, our group will spend the majority of our time perfecting the plastic treating process.

Grant researched various types of molding processes and determined which would lend itself best to our capabilities. This will guide our attempts to create upcycled plastic products, while also narrowing our focus on one technique so that we achieve our goals promptly. Additionally, his research provided baseline pricing for aluminum from different manufacturers, so that we can keep our project under budget.

Thomas was assigned to research plastic properties. His research mainly covers the melting point, hardness, and density of HDPE and PP. These properties will be important in configuring the press to melt the plastic we put into the molds. We want a plastic that is hard and resistant to scratching to reduce microplastic production as well as durable enough to not break if dropped or stressed under normal conditions.

Anna researched the testing that goes into plastic types and the materials needed for that. Her research shows how critical testing plastic is within the life of a polymer, what types of testing are typically done, what equipment that is used in polymer testing, and some data on the different types of plastics.

Kendall researched the ethics and environmental impacts of the process of recycling plastic. She found information on VOCs, and how melting plastics give off harmful fumes and resins that are toxic for living beings and the environment. Therefore, the group needs to determine the balance between melting temperature and the amount of plastic that will give off the least toxins. Molds for containers of food or drinks need to be avoided because of the possibility of the resins leaching into the consumables. Aside from that, within each chasing arrows symbol category there are differences within the plastic makeup so we must perfect the method with one specific source of plastic. The process of repurposing the plastic is also energy-intensive so to cut down on carbon emissions it is important to be as efficient as possible.

Honors Component Background Research

Polypropylene (PP) is a thermoplastic polymer used in a variety of industries such as consumer goods, medical technology, military appliances, industrial applications, and the automotive industry [1]. PP is known for being rugged while lightweight and it can have a variety of textures depending on the polymerization process used to create it. PP does not absorb water and is resistant to acids, bases, and other chemical solvents. Additionally PP can tolerate high temperatures , like 160°C, without melting [2].

There are two major types of PP used in the market, polypropylene homopolymer and polypropylene copolymer. PP homopolymer is more commonly used than PP copolymer and is used in applications like packaging, pipes, and electrical devices. PP copolymer is divided into random copolymers and block copolymers. Since random copolymers are optically clear and flexible, they are mainly used in products that need transparency. PP block copolymers are tougher than random copolymer which makes them suitable for applications that require high strength [1].

SENIOR PROJECT PLASTIC AND MOLD SELECTION

For our project, there were a number of thermoplastic polymers that we considered using to recycle into coasters (Table 1). Other than HDPE and LDPE, we were looking into PP because it is almost as common as HDPE, LDPE, and PE in general and it also has a similar melting point and mechanical properties. The major downside to it is the inability for PP to mix or blend with PE during melting. Although we did not do extensive testing for blendability between PP and PE, our general research suggests we avoid doing so.

Table 1. Thermoplastic Polymer Pugh Table

	LDPE	HDPE	PP
Availability	+	+	0
Blendability	+	+	-
Melting Point around 120°C	+	+	+
Hardness	0	+	+
Final	3	4	1

When deciding aspects of our coaster mold design, we had to consider the options of how we could machine our mold (Table 2). The two methods of machining we could use in this instance were using a lathe or a mill. Both have their advantages and disadvantages due to ease of use and machining capabilities. The primary modifications we wished to make and made were related to creating a lip to leave a cavity for condensation from cold drinks to gather as well as vertical channels in that cavity to prevent a vacuum from occurring under a glass, causing the coaster to be lifted with the drink.

Table 2. Mold Design Considerations Pugh Table

	Lathe	Mill
Limited Skill Usability	+	-
Vertical Cut Capability	-	+
Round Cut Capability	+	+
Chamfered/Filleted Edges	+	0
Image/Text Cut Capability	-	+
Holding Cut Material in Place	+	-
Final	2	1

SENIOR PROJECT DESIGN WORK

Overview of Designed Process

We designed a process that takes plastic that would otherwise be discarded and transforms it into a coaster using a heat press. The process takes approximately 30 minutes to create one coaster. This is if process steps are not occurring simultaneously. If process steps are being performed in parallel, more than one coaster can be created in half an hour. Our designed process consists of plastic collection and treatment, pressing the plastic, and cooling and extraction of the finished coaster.

Plastic Collection and Treatment

Our process begins with collecting LDPE and HDPE. We individually collected LDPE and HDPE and stored it in the Fablab. Then we washed the plastic in lukewarm water with soap. Then we let the plastic dry completely to prevent mold from growing. Next we cut the plastic into smaller pieces if necessary. We did this using either scissors or a blender with water. Through various tests (refer to "Testing" section of report), we determined that plastic piece size does not affect the quality of our coaster.

Pressing

The first step in pressing the plastic is loading the shredded or cut plastic into the mold ring on top of the thin aluminum sheet on the overhang of the work surface. Next, we arranged the Force over the loaded mold ring and slid the mold components into place under the middle of the press. Then, we clamped the mold ring to the work surface to ensure even pressure. Lastly, we used the press to apply 130℃ of heat and 45 psi of pressure to the piece for 10 minutes.

Cooling and Extraction

To extract the mold, we released the pressure on the press, loosened the clamps, and slid the mold out of the press. Then, we submerged the entire mold and coaster into a bucket of water for two minutes to allow the plastic to cool. After two minutes had passed, we verified that the mold was cool enough to touch. Then, we loosened the two clamps holding the base and Force together. Finally, the coaster was ejected from the Force. We were unable to find a reliable method to remove the coaster from the Force before we left. We tried using WD-40 which worked relatively well but we were unable to perform multiple tests using WD-40. The three methods that we used to extract the coaster are as follows: removing by hand by pulling on the plastic, removing by tapping with a dead blow hammer, or removal by hitting with a dead blow hammer while the Force is held in a vice. We do not recommend using the final method of removal since it could damage the quality of the coaster.

HONORS COMPONENT PLANNED DESIGN WORK

If I had access to the Fabrication Laboratory, my plan was to mirror the process that my group followed with PP instead of HDPE and LDPE. I would begin by determining the optimal plastic piece size for pressing by conducting blender tests and cutting the plastic with scissors. Once piece size was determined, I would begin creating coasters and test their quality, rigidity, and uniformity. During the pressing phase, I would also decide the optimal press settings in terms of pressure, time, and temperature. After I completed the pressing stage, I would move to cooling and extraction. If my experiments yielded the same or extremely similar results, then future senior project groups would have a third plastic to create coasters if they decide to continue our process. If my tests resulted in different press settings or cooling methods, then my plan was to create an additional set of instructions that future groups could use if they wanted to create coasters using PP instead of HDPE or LDPE.

SENIOR PROJECT TESTING RESULTS AND ANALYSES

Plastic Shredding Tests

Kendall, Grant, and Lianne began testing plastic shredding methods using a blender and adding water. They began blending plastic pieces (ranging from 1.5"/side to 3"/side) at the lowest setting of 1 for 30 seconds with no water. This resulted in scratches on the plastic but minimal shredding of the plastic. They tested each blending speed (1, 2, 3, and pulse) for 30 seconds with similar results

One of the difficulties in getting the plastic to shred was that the plastic pieces would not come in contact with the blades frequently but instead would be whipped around in the blender. Larger pieces in particular would be kicked up to the top of the blender and simply stay there, instead of falling back towards the blades to be shredded.

Using a blender speed of 3 seemed to shred the plastic the best, so the next few tests were conducted with a blender speed of 3. Additionally, the smaller precut plastic pieces that were put in the blender seemed to shred better than the larger precut plastic pieces. Therefore, all the plastic pieces were cut to approximately 1.5" or less on each side before putting them in the blender.

For the next tests Kendall, Grant, and Lianne added various amounts of water to see if water would help shred the plastic and increase blade contact. For all tests, the plastic pieces were already in the blender when water was added. We began filling the blender with water to 100 mL. This first test was unique compared to the following water tests since the plastic pieces that were in the blender were previously blended for 30 seconds at a blender speed of 3. This test shredded the plastic significantly. For the next test, we filled the blender with water to 300 mL with similar results. We decided that blending for a longer amount of time might increase shredding, so they shredded the plastic for 60 seconds with 1 L of water. After seeing good results, we shredded the same batch of plastic for an additional 30 seconds which did not seem to do much. Therefore, we determined that 60 seconds was the optimal amount of time to blend. The last test that Kendall, Grant, and Lianne conducted was adding enough water to submerge all of the plastic which ended up being 500 mL. This test gave similar results as the previous test using 1 L of water.

Heat Pressing Tests

The course of the year saw many trials with varying degrees of success, until our group was finally able to obtain consistent results towards the latter part of the fall semester, and the beginning of the spring. The following paragraphs show our trial, comments, and results we recorded during the fall semester.

Our group performed four tests using the heat press. We kept the heat press temperature consistent at 130°C for all the tests. The first test that we conducted was using a pressure of 80 psi for 5 minutes. For this test, we used white bottle caps and rings in the aluminum mold. A majority of the plastic overmolded out from the bottom of the mold because the pressure was too high. The plastic also had a ridged texture from the cylinder of the mold. For all of the following tests, we used parchment paper on the cylinder so the plastic would not have ridges.

For the next test, we used plastic pieces that were shredded in 1 L of water for a minute at a blender speed of 3. The press pressure was set to 20 psi and we pressed the plastic for 3 minutes in the aluminum mold. The pressure was too low and the time was too short so the plastic did not fully melt. Only the bottom side of the plastic melted.

We raised the pressure to 40 psi for the next test. We used three purple caps in the aluminum mold for 5 minutes. The plastic did not flow uniformly and overmold formed again. The overmold that formed was much less than the overmold that formed from the first test.

The last test that we performed was with the finely shredded plastic (4 cups of plastic, 6 cups of water, blender speed of 3, blended for 4 minutes). It was done using a pressure of 30 psi for 10 minutes. The plastic molded into a 1 cm thick disk with a slight wave texture due to uneven cooling but there was little overmolding. To eject the plastic from the mold, we flipped the mold upside down and let the ring fall slowly off of the cylinder which revealed the best result.

During our most recent heat press (Fall semester) testing, we came across a very effective process that gave us a rigid pressed disk of polyethylene with very little flash, no "wavy" surface texture, complete melting of polyethylene press material, and little to no warping due to cooling. Although our current method is currently not time efficient, we know it works. To achieve the aforementioned pressed disk, we fill the aluminum mold ring with either shredded or manually cut polyethylene fragments. For greater disk thickness, we had to use cut out layers of polyethylene since the shredded material cannot be compressed as it is loaded into the mold ring and the aluminum Force cylinder is placed on top. After loading the mold and placing it into the press, the bottom mold ring is clamped to the bottom press plate using all steel clamps to ensure the ring does not rise and allow polyethylene to escape while under pressure. Finally, after being pressed under 30 psi at 130°C for 10 minutes, the heated plates are unplugged and the part, mold, and press are allowed to cool over the course of roughly 6 hours until the part is ejected the following day. The main takeaway from this is that the polyethylene disk must cool while under pressure to ensure minimal thermal warping. Figure 1 shows a progression of the results of our pressed plastic tests.

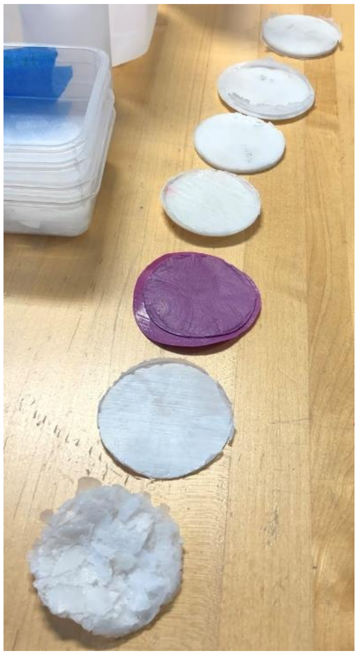

Figure 1. Progression of plastic disks using press.

Following the progression of results during the fall, our group finally figured out how to consistently make a quality product. The only struggle that persisted was the occasional bit of flash (excess plastic) that stuck to the edges of the final product. This was easily overcome by simply trimming the edges. See figure 2 to view an example of what our coasters looked like during all trials through the spring semester.

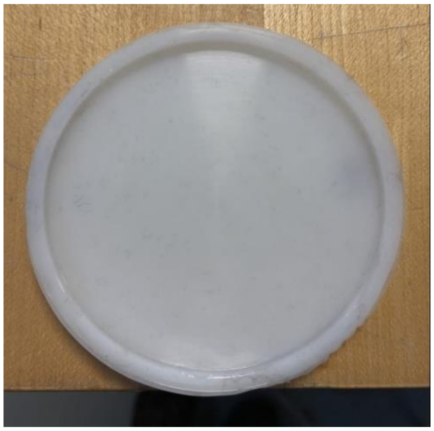

Figure 2. Final example of finished coaster.

In summary, it took us a while figuring out how to properly produce a usable coaster, but eventually we found a consistent shape. The main takeaways we gathered from our years' worth of testing are that particle size of plastic did not matter, consistent pressing settings were vital, and having proper constraints around the plastic was most important to get consistently commendable results.

Cooling Tests

Optimizing our run time by shortening the duration it took for our mold to cool was our final large challenge during the semester. While many plans were discussed from simply letting cold air dry it, to using a hose/spray bottle, to attaching a water vat to the press, ultimately, we decided on simply using a large plastic container filled with water to submerge the mold. This was very simple to implement, and its addition sped up our run time significantly. At first it took us around 90 minutes between trials. Now we could do tests roughly every 20 minutes. This yielded a runtime reduction of 78%.

To better understand our thoughts and processes while testing this method, read the following paragraphs detailing our reflections.

We conducted several tests to determine a method for quickly cooling the mold after each press run. Our current procedure involves letting the mold and press cool while still under pressure. It takes roughly ninety minutes for the mold and press to cool enough to eject the plastic. We ran two preliminary tests that involved heating a piece of aluminum that is similar to our mold to about 180°C and dropping it into 20°C water. 180°C is about 50°C above the typical mold operating temperature. The aluminum cooled to about 22°C within a minute. At this temperature, it is safe to handle our heated molds.

We conducted two additional tests to see how heated plastic would react when submerged in room temperature water. For the first test, we used pieces of water bottle caps and the necks of milk jugs. After ejecting the mold from the press, we quickly submerged the entire mold into a bin of room temperature water to cool. This resulted in a disk that was warped on the bottom but smooth on the to. To prevent warping, we used a thin aluminum plate on the bottom of the mold instead of parchment paper. Afterward, we submerged the entire mold into water immediately after releasing the press. This resulted in a disk with little to no warping and minimal flash or overmolding. For this trial, we used leftover shredded plastic pieces from last semester along with a blue plastic ring. We will continue to test different processes of cooling in the following weeks for optimization. Based on the results, we currently have a viable option to quickly cool the mold.

This method of cooling stuck due to its success, and we used it for the rest of our trials before the semester concluded upon short notice. Nevertheless, the we were still able to conduct a plentiful number of tests thanks to this addition to our process.

Works Cited

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[2] CableOrganizer.com, “The Facts on Polypropylene,” *Facts about Polypropylene: What it is and Where is it Used?*, 24-Aug-2018. [Online]. Available: https://www.cableorganizer.com/learning-center/articles/facts-on-polypropylene.html. [Accessed: 10-Feb-2020].

APPENDIX: Background Research

Compression Molding

Compression molding is a molding process used to create stock shape materials out of a preheated polymer. The polymers, normally either thermoset or thermoplastic composites, are placed in the mold cavity and hardened into the desired shape through cycles of heat and pressure [1]. Compression molding can produce many types of parts with varying characteristics such as thickness, length, and complexity. The resulting objects are also high in strength [2]. Compression molding is also one of the least expensive methods to mass-produce products. Additionally, it is highly efficient since it wastes a minimal amount of material and energy [3]. The compression molding process is similar to making waffles in a waffle machine [4].

Composite materials are highly anisotropic which allows for reinforcement to be placed only where needed in efficient designs. Once cured, modification of the composite material is limited [5]. Thermoset composites are normally based on glass, carbon, or aramid fibers and are commonly incorporated with resins such as polyesters, epoxies, vinyl esters, bismaleimides, cyanate esters, polyimides, or phenolics [5]. Thermosetting compounds are alternated with layers of different reinforcement materials for the final product in compression molding [4]. These composites are pliable plastics that once heated and set to a shape may not be changed. Thermoplastics can be reheated and cooled as much as necessary since they harden as a result of being heated to a liquid state and then cooled [3]. Thermoplastics pellets soften when heated and become more fluid as the temperature increases. These composites are similar to butter since butter can be melted and cooled many times to form several shapes just like butter [6].

There are four main steps for compression molding of thermoset composite materials. First, a two-part, high strength metallic mold is created. Next, the desired composite is pre-formed into the shape of the mold. This step is crucial because it helps improve the performance of the finished part. Third, the pre-formed part is placed into the heated mold and compressed with pressures ranging from 800psi to 2000psi. The exact pressure used depends on the thickness of the part and the material used. Lastly, the part is removed from the mold once the pressure is released. Any additional cleaning of flash is also part of this last step [2].

The three most common types of molds used in compression molding of plastics are flash, straight, and landed. Flash requires that accurate product be inserted into the mold, then the flash is removed. Straight does not require that an accurate product be inserted into the mold but still requires the removal of flash. Landed requires that an accurate product be inserted into the mold but flash does not need to be removed afterward [3].

Factors that must be considered when compression molding consists of the material, shape, pressure, temperature, part thickness, and cycle time [3]. The temperature of the plastic polymer is a vital factor that affects compression molding. If the plastic polymer is not heated to the appropriate temperature, it may not fill the mold cavity completely. If the plastic polymer is heated too much, it might create an excessive amount of pressure while requiring a longer cooling time [7].

Some of the advantages of compression molding include relatively low tooling costs, minimal residual stress left in the stock shape [4], complex part creation, stiffer and stronger materials because of the ability to use longer fibers, and parts that are more resistant to corrosion than their metal counterparts. Compression molding can be viewed as a middle ground between plastic injection molding and laminated compound fabrication [2].

<u>Molding Process</u>

When it comes to molding plastic, there are a few common options such as extrusion molding, compression molding, blow molding, rotational molding, injection molding, and thermoforming [8]. Since we have limited resources available to us, thermoforming with the heat press was our only viable option. Luckily though, thermoforming is perfect for smaller applications where it is not necessary to create models on a large production scale. It works almost identically to compression molding but it requires less pressure since it uses the aid of heating elements inside the two compression plates. These plates squeeze together the mold and use heat to fully melt the plastic into the desired shape [8]. The mold itself then needs to cool before the finished product can be taken out and used. This technique is also generally low cost because of the relatively low pressure it uses compared to other processes [8]. Another perk associated with thermoforming is that it allows us to use aluminum, which is cheap and very easy to work with given the tools we have in the lab.

Aluminum itself can be purchased in almost any desired length. Prices range anywhere from around $6 to $70 per bar. Common sizes range from 1" x 1.25" x * to 1" x 0.25" x *. (* any length bar that is desired between 1' and 12') [9][10]. For our purposes, we should only need to purchase a foot long piece with a cross-section of 1"x1.25". If our project goes well, and we have the extra time to make more molds then more would need to be purchased.

<u>Plastic Properties</u>

Hundreds of different polymers or plastics are used today. Two of the polymers that we had in mind for using in the molds of our press are High-Density Polyethylene (HDPE) and Polypropylene (PP). HDPE is a polyethylene that is used to make plastic milk bottles, plastic bottle caps, plastic bags, plastic laundry baskets, and more. PP is a denser polymer that is used to make Tupperware (food containers), plastic lids, some plastic foam packaging, plastic automotive components, and more. They are both readily available due to their widespread use.

The melting point, hardness, and density are the three main properties we are interested in for forming and using our plastic. The melting point for HDPE is about 120-140°C [12][13] while PP is about 140-170°C [11][13]. The hardness of HDPE on the Rockwell scale at 22.8°C is about 55-94 [12] while PP on the Rockwell scale at 22.8°C is about 67-113 [11]. The density of HDPE and PP are both about 0.9 g/cm^3 [11][12][13]. With this information, we can decide what polymer we plan on using when we are ready to start using our molds.

<u>Plastic/Material Testing</u>

Many different processes need to be considered when it comes to testing plastics. Some aspects that need to be considered are the many types of testing, the equipment that is involved within the testing process, and how complex this testing can be. The top six different kinds of testing are Melt Flow Testing, Impact Testing (Drop Tower), Impact Testing (Pendulum), Mechanical Testing, Rheology, and Thermal Testing [14]. Chemical testing is also highly important to make sure the plastic being used is suitable for the product. This part of testing is highly complex; however, it provides a lot of insight into the material. Some of the data from previous chemical tests can be found and used to save time [15]. Testing is a critical part in the role of plastics and the final product needs to be considered when performing such tests.

Equipment also plays a huge role in plastic testing. This equipment includes both physical equipment and electronic equipment such as software. The equipment is often used for measuring temperature, tensile strength, and adhesion properties. There is also equipment to see if the plastic contains any reinforcing materials or additives [16]. The plastics testing industry is vastly growing and is currently in huge demand; therefore, some of the testing can be pricey.

Plastic Safety Research

When melting polyethylene, we have to consider the fumes that are emitted since the FabLab does not have a ventilation system designed for melting plastic. One of the most dangerous fumes emitted is dioxins. Dioxins are toxic to humans and are carcinogenic and hormone disruptors. Dioxins can also accumulate in body fat [17]. Some of the immediate possible side-effects are irritation of the nose, lungs, and eyes; however, prolonged exposure can cause cancer, impotence, and asthma [18]. As a group, it is important to consider these things when we are around the melted plastic for prolonged periods in a space that is not well vented.

Ethics

One main ethical issue with melting plastic to repurpose it is that the process creates Volatile Organic Compounds (VOC). The fumes are harmful to both the environment and the living beings coming in contact with them [19]. Due to the VOC, the group will need to research the plastics we may use and a process which will release the least amount of VOC as possible. The temperature at which we melt the plastic and what it comes into contact with will affect this. Because of the petroleum base of the plastics, melting it will create a resin that can leach into the consumable item [19]. While the resin is not very harmful through physical contact, the impact is much greater when ingested. Certain plastics and plasticizers used to make them are being linked to many health concerns and are being banned from use in food containers like baby bottles [20]. Therefore, we must not make molds for food or beverage containers.

Melting the plastic and running the heat press is also energy-intensive and has a carbon impact. Elizabethtown College obtains some of its energy through the solar array, so using the heat press does not contribute as highly to CO_2 emissions as it would if used elsewhere. One advantage to recycled plastic is that "it takes two-thirds less energy to make products from recycled plastic than from virgin plastic" [21]. Since the plastics used will be sourced here at E-town, there will not be additional emissions produced by recycling truck transportation. Additional life-cycle aspects aside from emissions are the contaminated water post-cleansing, possible packaging waste for product sales in the bookstore, and eventual product disposal after use.

The water used in cleansing the HDPE before melting will have different chemicals or food particles in it depending on the use of the initial product. The used water will then have to be treated by a water treatment plant. If a product that we create ends up being sold in the Elizabethtown College bookstore, the school will dictate how the product would be packaged for sale. This packaging will then be disposed of after purchase and add to the waste flow. Eventually, our product will either be entered back into the recycling chain or sent to a waste disposal facility.

Having our recycled merchandise be sold by the school will have little negative impact on the market. Because we are not selling and distributing on a large scale, we will not outcompete any local or global business. Any company that would sell products to the college will most likely still be able to work with the school. Recycling plants will also not lose much, if any, revenue because of our project. The plastics we will use are the small pieces that tend to get lost or tossed aside in large scale processing, as noted in the problem statement.

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