OUR KILO

Creating filament from LOCAL HOUSEHOLD PET

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SUMMARY:

This document shows the learnings in recycling PET household objects, containers, and bottles that were collected by people in the neighborhood of OurkilO, children from local schools, and retrieved by ByeWaste. The aim was to reuse the plastic material for 3D-printed objects. In this document, we explain the steps we followed to achieve a printable spool of PET using shredded plastic from local household PET. It shows a labor-intensive process, identifying 6 steps in the pre-treatment. We followed the recycled steps, that we conduct in our usual process and managed to achieve some usable filament, however only a very limited amount of the collected household plastic.

TYPE IN OF INPUT

| Picture 1: Wrong types of plastic.

| Picture 2: transparent vaccum-formed PET

| Picture 3: Transparent blow-molded PET

| Picture 4: PET after cutting hard to peel labels.

The consumer waste consisted mainly of household items, such as vegetable/ fruit containers, cleaning containers and bottles, drink bottles, and beauty products packaging among others.

PRE-TREATMENT:

Step 1- control if all is PET plastic-Although people were instructed about collecting only PET plastic, also a lot of other plastic types were brought in. Meaning we needed to separate PET and throw out all the other types of plastic. Of the collected material, approximately 75% was indeed PET.

| Picture 1

Step 2- Separate the PET in categories- Once it was assured that all left was PET, we sorted them into the following production types of plastic:

1) Vacuum formed PET

| Picture 2

2) Blow molded PET

| Picture 3

Additionally, there were transparent and coloured PET. We chose transparent and colored to conduct different kinds of experiments. Colored PET can be used in smaller quantities to add color to transparent batches.

| Picture 4

All transparent plastic was put together. We didn’t choose to separate different types (i.e. RPET, PETE, APET) because in an ideal recycling scenario, you would want all of them to be processed together to achieve the highest yield of filament. Also, processing on this level would make the process even more complex.

|

RECYCLING PROCESS

Picture 5: A good example of easy-to-clean material, these fabric softener bottles were great to recycle and left no residue of the label behind.

Picture 6: Example of material brought to the studio from people in the neighborhood that are not PET, therefore it could not be used in the filament making process.

Picture 7: Example of shredded PET flakes.

Picture 8: Colored plastic shredded flakes.

Step 3- Remove labels / other plastic -After the first separation, we then needed to separate the parts of other plastic from the PET containers like HDPE lids and caps, also plastic foils, covers and taking out the labels.

This was done either by peeling off by hand or cutting them out with an Exacto-knife. Some labels don't come off easily, that's why they had to be cut out (see the blue trays on the image above) while others only had a small strip of adhesive: meaning they would come out in one piece and leave no trace behind.

Picture 5, Picture 6

Step 4- Cleaning-After removing all labels/ wraps/ stickers, the plastic is washed in a washing machine at 90 degrees to be entirely empty of the previous contents. Washing it at a high temperature causes them to melt and deform. This results in a more solid structure, which supports grabbing by the teeth of the shredder. However, this is not necessary, with a minimum of 60 degrees this cleaning method is effective to remove all of the bottle's contents. While still being a more environmentally consciouss option to save water and energy.

Step 5 - Drying-Once the cleaning is completed and before being processed in the shredder machine, the plastic should be left to dry completely.

Step 6 -Shredding-Our shredder is very effective at shredding the PET plastic. However, PET is a very ductile material compared to other plastics, such as PLA. This means that it takes longer to be granulated inside the machine, and the machine needs to run continuously to granulate all the plastic deposited inside, sometimes even needing to be emptied manually. The machines cannot be fed too much at the same time, it would cause the shredder to stop, due to accumulated material inside the granulator chamber.

Picture 7, Picture 8

EFFECTS OF PET MANUFACTURING ON FILAMENT-MAKING PROCESS

Blow molding (or moulding) is a manufacturing process for forming hollow plastic parts.

Thermoforming is a manufacturing process where a plastic sheet is heated to a pliable forming temperature, formed to a specific shape in a mould, and trimmed to create a usable product.

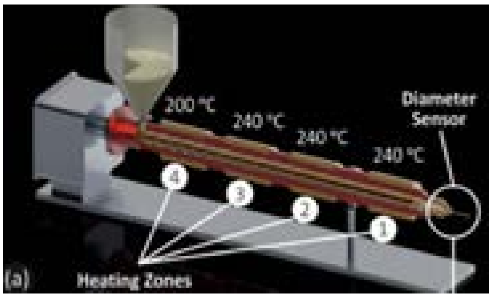
Vacuum forming is a simplified version of thermoforming, where a sheet of plastic is heated to a forming temperature, stretched onto a single-surface mould, and forced against the mould by a vacuum.

Source: wikipedia

It became evident that the way in which the plastic was handled before recycling has a different effect in the spoiling process. The blow-molded bottles and containers resulted in better flaked material for spooling, due to how they handle temperature and also the thickness of the material. The flakes were heavier and allowed for easier feeding into the hopper.

Vacuum-formed plastics resulted in very liquid filament coming out of the machine, similar to hairs (See images below). Because of that, we could not achieve usable filament from vacuum-formed PET flakes. For the next steps of the blow molded bottles, we refer to the report of Blow-molded PET since that followed the same treatment after shredding.

EXPERIMENTING WITH VACUUM FORMED PLASTIC



Picture 9: Model image of what happens in a mixing screw and the placement of the four different heating zones (H): source: Vidakis et al. (2022)

Go to link

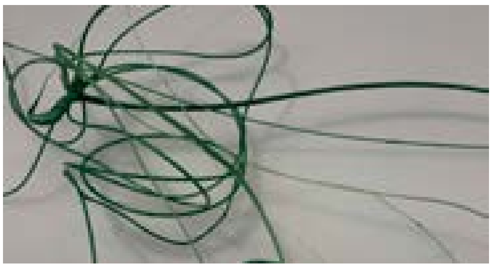
H4- 230° H3- 230° H2- 230° H1- 230°

Picture 10: Low temperatures can push the material better out of the nozzle. However in this case 230 degrees was not enough to melt the plastic fully.

H4- 230° H3- 230° H2- 235° H1- 235°

Picture 11: Test to see how low the temperature can be to be fully molten, the extra 5 degrees were still not enough.

H4- 235° H3- 240° H2- 245° H1- 245°



Picture 12: This setting then produced thinner strands but without being able to be consistent.

This is a series of examples of how we test the material using different settings in the machine to produce filament. In this series I experimented with changing the temperature throughout the mixing screw using a mixture of 50% Colored PET and 50% PETG granulate.

To quickly explain this, PET plastic is very viscous and liquid, and the goal is to achieve a temperature setting that is able to push a constant stream of molten plastic out of the nozzle to create a filament thick enough to be used.

Picture 9

We conducted several rounds of experiments to create recipes for the filament-making process using different mixtures of plastics in the machine and different temperature settings.

Test 1: 100% Vacuum-formed PET in the filament maker resulted in thin strands of unusable filament.

Test 2: 50% Vacuum-formed and 50% Blow-molded PET in the filament maker resulted in wild changes in flow rate, causing the filament to alternate between thin and thicker strands.

Test 3: 50% Vacuum-formed and 50% PETG in the filament machine resulted in the same alternating flow rate of the previous test. The filament was never consistent enough to start the spooling process.

With the results of Test 2, we experimented also with temperature settings, this led to varying results, but still without achieving useable filament.

Picture 10, picture 11, picture 12

EXPERIMENTING WITH VACUUM FORMED PLASTIC

Picture 14: Same mixture of PET and PETG plastic but on the left using vacuum formed and on the right blow-molded

Picture 15: Same mixture of PET and PETG plastic: on the left using vacuum formed and on the right blow-molded

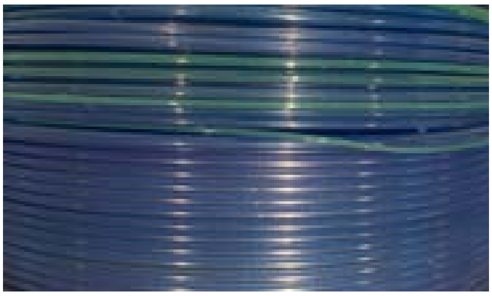
We have 2 tests showing that, when using flakes of vacuum-formed PET, we cannot achieve a constant flow high enough to create usable filament. The usable filament is in the range of 1.6 to 1.9mm diameter, and the filament portrayed on the left side of the pictures is around .9 mm. This is most likely caused by how this specific type of PET reacts to heat, making it difficult to push out the molten material out of the machine.

Picture 14, Picture 15

SUCCESSFUL ATTEMPT USING PET AS COLORANT FOR PETG FILAMENT MAKING

H4- 242° H3- 244° H2- 250° H1- 250°

Picture 16: Mixture of 80% PETG and 20% colored PET gives a good result to produce filament, this further confirms that the higher concentration of vacuum-formed PET is what causes the disruption of the filament making process.



Picture 17: easily noticeable by the green color, the new mixture suddenly becomes thinner and thinner until it cannot be spooled anymore.

To remediate that we have tried mixing it with other types of PET, such as blow-molded PET and PETG, a 50-50% mixture still does not present usable results.

Comparison between strands of filament made from blow-molded plastic vs vacuum formed.

The following test presented positive results to use colored PET flakes both vacuum formed and blow molded as a colorant in smaller ratios in a PETG mixture

Picture 16,

Seeing that this test gives good consistent results, a higher concentration of PET was added to the mixture. This time 50% PETG with 50% vacuum formed: the results are almost immediate, the process is disrupted.

Picture 17

PRINTING WITH RECYCLED RPET

Picture 18: Example of printing settings using a recycled spool.

We print our objects with a: 0 .8 or 1mm nozzle

That is to achieve a chunky look but also to avoid impurities from clogging the nozzle. Clogging is a physical constraint, meaning either the filament was too thick to go through the heating element or there is a piece of alien material that does not melt and now is stuck inside the nozzle. A bigger hole in the nozzle means bigger particles can go through.

The BED has to be set at a minimum of 75° degrees to maintain adhesion to the PET and the nozzle set between 245° and 255° degrees to melt the plastic at the optimum rate for printing.

| Picture 18

To facilitate the testing of the material, we operated with a printer that has a clog detector attachment (Clog Detector – Modix Large 3D Printers). This is a sensor that detects if the filament is still moving- if not the print is paused so that you can inspect it, remove the bad part of the filament and reload the plastic to continue printing.

IDENTIFIED ISSUES WHEN PRINTING:

In our process, we have identified a few issues that happen when printing with a spool that was not 100% consistent in diameter or free of impurities.

1) Stoppages- Due to Cloging: When printing with our spools, we observe that is common to have a clog just before the filament gets to the nozzle. This happens because occasionally the filament gets too thick and cannot be pushed through into the nozzle. This causes the machine to stop and you have to remove the filament from the machine, cut the bad piece and return the filament back into the machine.

Due to insufficient feeding: The opposite can also happen, if the filament gets too thin the gears in the extruder cannot push enough filament into the nozzle, thus causing the clog sensor to be triggered and stop the machine. The process to restore the machine is the same as the one above.

This can happen a few times per print depending on the size and duration of a print. This implies that designs of small objects are better suitable. The smaller the piece lowers the chance to encounter a bad piece and run through enough filament, thus avoiding it to stop. We noticed that 30 minutes to an hour prints are the best size to avoid stoppages.

2) Print Quality-Crystallization and Cooling issues: PET plastic is good for printing simple shapes, usually printing spirally. This is because quick and short movements cause the crystallization of the material, with the nozzle moving quickly close to itself it causes the plastic to either not cool completely before being touched by the nozzle again which makes it look like the top of the ice cream below, or to cool too slowly which causes it to crystalize and become brittle, like the lighter tip of the icecream below. The previously mentioned PETG addition helps with this problem and stabilizes the material but does not solve it completely, complex shapes will still cause the nozzle to move too quickly near itself and crystalization happens once again.

CONCLUSION

Creating PET filament from post-consumer waste streams hasn't been an easy challenge. We have identified the outliers in the process: Vacuum-formed PET which, unfortunately, is the bulk of the recycled plastic received.

For most blow-molded, which are mostly bottles, a good recycling system is in place using the 'statiegeld' collecting stations. For the detergents/ washing bottles, the statiegeld is not in place. OurkilO could make a strong suggestion to do so as well. The results and pilot of this are in the report of blow-molded PET.

So far we were not able to produce a usable spool of PET using vacuum-formed plastic containers, only blow-molded plastic. The vacuum-formed plastic can however be used as a coloring agent for transparent PETG granules.

MORE INFORMATION