OUR KILO

Creating filament from Blow-molded PET

OURKILO REPORT

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SUMMARY:

This document shows the learnings in recycling PET household bottles that were collected at the WIBRA, containing cleaning liquids, beauty products, and food/drinks. The first sorting and collecting were done by Impackt!. The aim was to reuse the plastic material for 3D-printed objects. In this document, we explain the following steps to achieve a printable spool of PET using shredded plastic from blow-molded PET containers.

RECYCLING PROCESS

1) Transparent PET/ RPET bottles.

Picture 1

2) Colored PET/RPET bottles.

Picture 2

Picture 3: 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 4: Examples of bottles that needed to have the labels cut out by hand.

Picture 5: Coloured flakes

Picture 6: transparent flakes

WE HAVE RECEIVED MAINLY 2 TYPES OF PLASTIC:

PRE-TREATMENT:

All collected plastic has been cleaned by using the following process:

Step 1- Try to take out the label. If it doesn't come out easily like the picture of the blue bottle, then the parts with leftover glue or stickering need to be cut out with a sharp tool. If that is not done, there will be other material mixed with the plastic -this other material has other process and melting characteristics, causing faulty filament.

Step 2- After removing all labels/ wraps/ stickers, the plastic is washed in a washing machine 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. In the end, we achieved good results with washing at a minimum of 60 degrees. This cleaning method is effective to remove all of the bottle's contents without the need to deform the plastic. Once the cleaning is completed the plastic should then be left to dry completely before being processed in the shredder machine.

Picture 3, Picture 4

Step 3- Shredding-Our shredder is very effective at shredding the PET plastic after the first two steps, 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. Consequently, the process takes longer and 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 5, Picture 6

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.

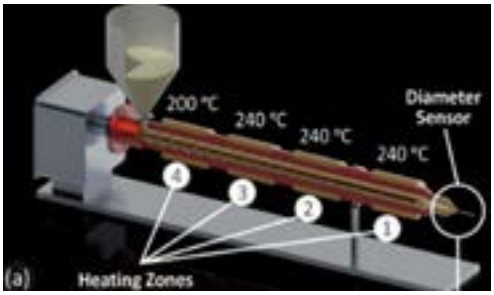
Source: wikipedia

We conducted several rounds of experiments to create recipes for the filament-making process using different mixtures of plastics in the machine, e.g. 50% blow-molded plastic and 50% injection-molded plastics. It became evident that the way in which the plastic was handled before recycling has an impact onthe spoiling process. Therefore, another sorting should be made into the PET catrories pre-production.In this case, we worked with 100% blow molded.

Blow-molded bottles and containers resulted in better materials 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. Heat-pressed plastics and injection molded plastics resulted in very liquid filament coming out of the machine, similar to hairs. Because of that, we could not achieve usable filament using vacuum-formed and injection-molded PET flakes.

CREATING THE SPOOL

Picture 7: A good example of spooled filament. (25% blue flakes 75% transparent PET flake mix)



Picture 8: 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

Our aim: recycled filament

At OurkilO we set the aim to create recycled filament since this would enable upcycling through the creative use of spools in the 3D printing facilities.

Our definition of a good spool is: Above 300gs in a single roll. A consistent diameter throughout the whole length of the spool, never going above 1.9mm, with interesting colour output.

Picture 7

The shredded plastic was processed in our designated PET filament maker machine, having the following temperatures at each of the temperature heating zones:

H4 - 242° H3 - 244° H2 - 250° H1 - 250°

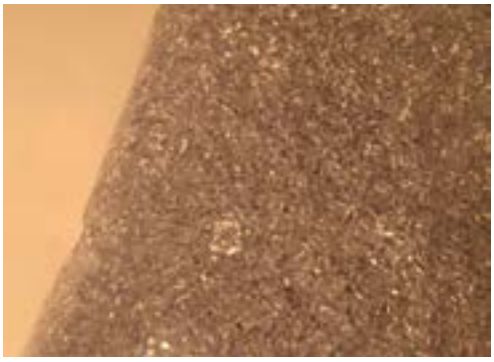
To quickly explain this, PET plastic is very viscous and liquid, and the goal is to achieve a temperature setting that is able to push a constant stream of molten plastic out of the nozzle to create a filament thick enough to be used.

Picture 8

With the temperature settings mentioned above, you can get to that consistency. Going lower would cause the material to come out brittle and bumpy, because it was not fully molten. At a higher temperature, the material would be too liquidy to spool with a round shape, making the strands of filament too flat (linguini) and tiny, which do not feed well into the printers.

CREATING A SPOOL

Picture 9: Granules from the shredded filament, giving it a rounder shape with more material volume.



Picture 10: Virgin PETG granules.

To ensure the constant stream of plastic through the mixing screw, there are 2 possible options:

1)Granulating a spool of PET to add granules to the plastic flakes

Picture 9

2) Adding 20% of PETG granules to the mixture of PET flakes.

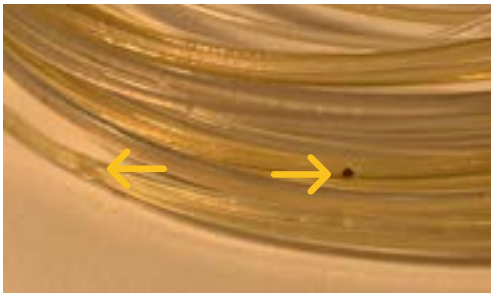
Picture 10

PETG is added to increase the volume of plastic inside the machine and to help with the feeding of plastic. The round shape of the granules is easier to fall down into the hopper of the filament maker. Thus, adding granules to the flakes prevents them from grabbing onto each other and creating a hole in the hopper. If that hole occurs the machine will suddenly produce very thin filament and disrupt the process entirely so it is essential to avoid that. Both of the 2 methods above help to remediate this issue, however PETG also has the added benefit of having Glycol in its composition, which makes the spool more resistant to moisture, which can accumulate in the plastic as it is a hygroscopic material. However with this option you won't achieve a 100% recycled spool since there would be virgin PETG granules in the mix. By working down from a 50-50% mix of PET flakes and PETG granulates, 20% is the lowest amount possible to mix that still gives the desired results mentioned above.

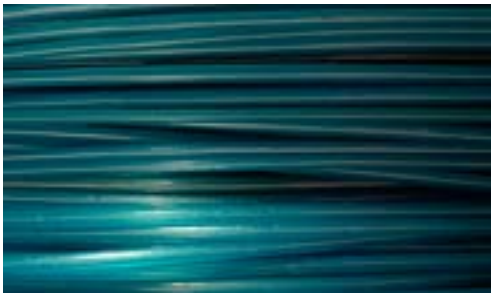
CREATING A SPOOL

Picture 11:Variety of printed objects using different mixtures of colored flakes.

Picture 12: Close-up of a colored spool.



Picture 13: Very noticeable piece of contamination inside the filament.



Picture 14:A good example of spooled filament. Consistent diameter and perfectly aligned.

ADDING COLOUR TO THE SPOOL

To get the same coloring results, we have noticed that 20% of the flakes being colored PET gives a consistent color throughout the spool. So, in a mixture of 100g of plastic, 20g should be colored PET flakes and 80g transparent PET flakes.

Picture 11

The length of the spool

A commercial spool PLA usually contains 1 kilogram. With PET, we wanted to match this. We managed to achieve consistent spool weights of around 300 grams. This is equivalent to around 150 meters of plastic filament. The reason for having a short length in the spool, ts that PET flows much slower than PLA, meaning that the machine has to run for longer to get to the same length. Also, PET is much more hygroscopic than PLA: it absorbs moisture which quickly has an effect on the diameter of the spool's filament. And lastly, PET is prone to have rat-holes in the hopper, meaning that there is air in between the screw and the rest of the plastic, causing the need to halt production.

Picture 12

Testing the quality of the spool

During the production process you need to continuously observe the spooling process, which can be done through the App from 3Devo, or by standing close to the machine. The main issues that need to be noticed are sudden drops or a raise in the diameter of the filament and/or contaminated material present in the filament. Once you have your PET spool checked you can proceed to print with it.

Picture 13 , Picture 14

Experimenting with the right settings

Every new batch of plastic, will require adjusting the machines to the right settings, based on the characteristics of the plastic, but also the conditions in the processing venue. To find the right temperature for the spooling, the experimentation always started at 260° throughout the mixing screw. Our filament maker has 4 heating zones, which can be separately controlled and are the variables to test with. The quality is inspected visually and through the assistance of the visual aid software DevoVision.

Below are some suggestions, for situation that might occur when spooling:

> Plastic comes out too liquid/ Falls out of the nozzle like syrup → lower the temperature

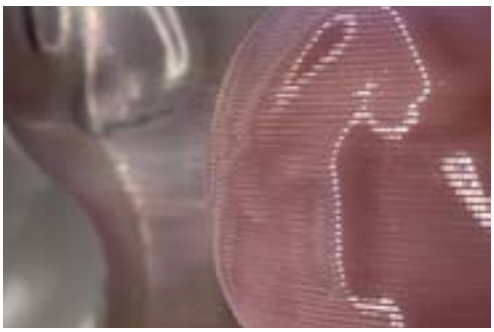
> there is an unstable flow in the screw → first heating zone might be too high

> the filament is brittle / breaks easily → temperature too low

> the filament is cloudy → raise the temperature overall to get it more glassy

PRINTING WITH RECYCLED RPET

Picture 15: Example of printing settings using a recycled spool.



Picture 16: A chunky look achieved with a bigger diameter nozzle.

We print our objects with a: 0.8 or 1mm nozzle

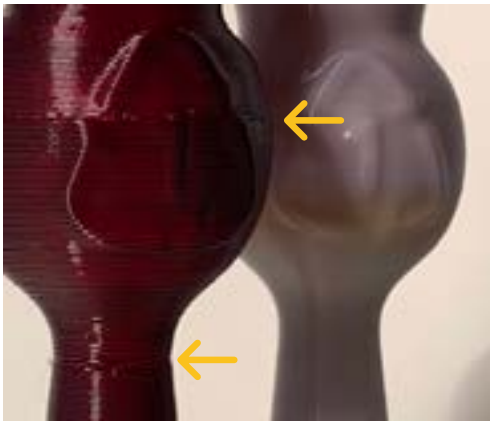
That is to achieve a chunky look but also to avoid impurities from clogging the nozzle. Clogging is a physical constraint, meaning either the filament was too thick to go through the heating element or there is a piece of alien material that does not melt and now is stuck inside the nozzle. A bigger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

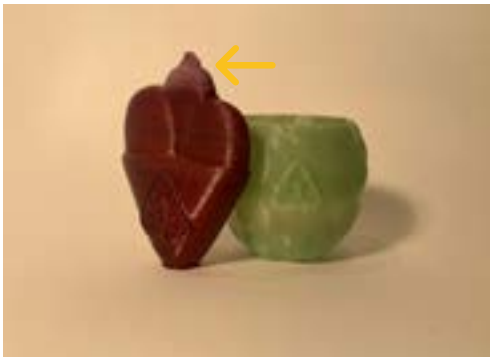
Picture 15

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



Picture 17: On the left is a print with 2 stoppages. That causes the faulty lines in the model.



Picture18: Failed prints: left is caused by too much detail in the top, the material has no time to cool and cristalyzes, and left was caused by a clogged nozzle.

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 (hence; contaminated).

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.

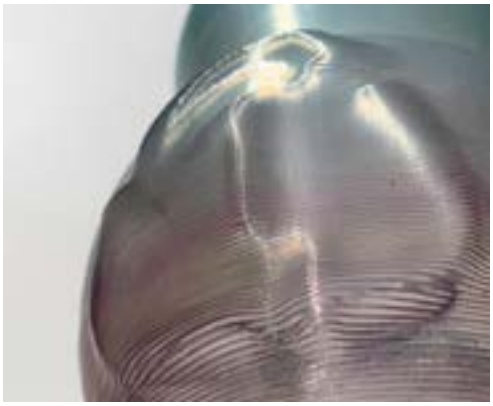
This can happen a few times per print depending on the size and duration of a print. This implies that designs of small objects are better suitable. The smaller the piece lowers the chance to encounter a bad piece and run through enough filament, thus avoiding it to stop. We noticed that 30 minutes to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

Picture 17

2) Print Quality- Our PET plastic is good for printing simple shapes, usually printing spirally. The reason for this is that quick and short movements cause the crystallization of the material. When the nozzle moving quickly close to itself it causes issues with the quality. The plastic doesn't cools completely before being touched by the nozzle again, which makes it look like the top of the ice cream below. Alternatively, it cools too slowly which causes it to crystalize and become brittle. 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.

Picture 18

CONCLUSION



We have achieved great results with printing the PET from blow molded detergents collected at the WIBRA. Being our best spools so far, they resulted in our prints with the least amount of stoppages, often with none at all.

An additional benefit of the recipe of 80% WIBRA PET and 20% Virgin PET-G was that it made the process more efficient. Because of the shape and material volume of PETG, there was no need to regrind the spool to achieve a solid quality of PET spool. This was partly also achieved due to the fact that blow-moldedd PET containers result in thicker flakes. Hence, the shape of the shredded materials have an influence on the quality of the spool.

On the other hand, this recipe does mean that the spool isn't 100% composed of recycled materials.

Having coloured and transparent PET is great from a creative standpoint, with the mixtures and recipes we have described above we managed to recycle the plastic and create spools with color. Something that we were not able to achieve before.

Lastly, we have adjusted our own printers to accommodate for PET printing with the following:

a) a custom printing head made from PETG with better cooling capabilities to prevent crystalization when printing (Due to taking too long to cool down the filament)

b) a clog sensor, that monitors the filament before it gets into the printing head.

c) Using a bigger nozzle to diminish the effect of contamination and prevent clogging inside the nozzle

For designing we made use of the following software tools:

a) blender
b) super slicer
c) meshmixer

Our designs specially made for PET can be found here:

OurkilO | Printables.com

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