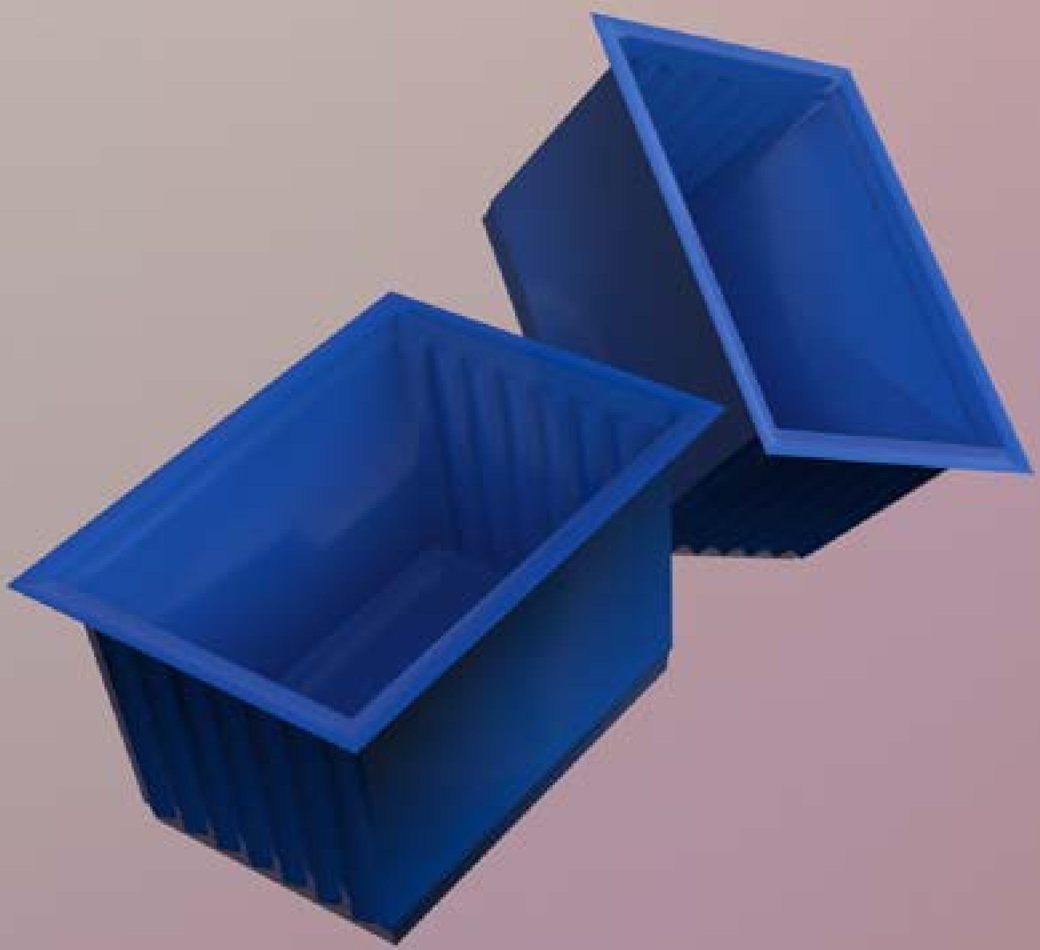
OUR KILO

Creating filament from Industrial Use PET



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SUMMARY:

This document shows the learnings in recycling PET cups and trays used by Koppert Cress for hydroponic farming. The aim was to reuse the plastic material for 3D-printed objects and investigate the options to create upcycled products for their own production. In this document, we explain the following steps to achieve a printable spool of PET using shredded plastic. Ultimately we didn't manage to create a production stream consistent enough to create a usable spool on a big enough scale for regular use. Our spools were mostly used for creating concept objects and prototypes, but the PET material proved itself too inconsistent and difficult to use in spool production. Partially because of the material properties but also due to the experiments being held in an environment with too many variables like moisture, and temperature.

RECYCLING PROCESS

We have received one type of plastic:

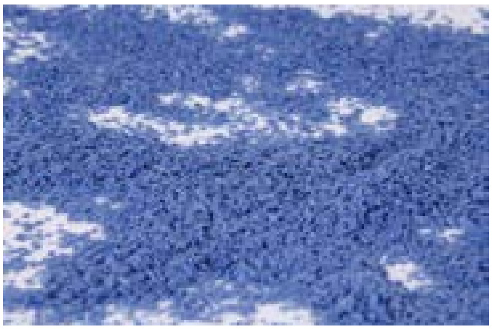
1) Transparent PET trays.

| Picture 1: Transparent trays after being cleaned

2) Blue PET Bakjes

| Picture 2: Blue containers with spots of fibers.

Picture 3: Example of material accumulating in the shredder



| Picture 4: Example of shredded PET flakes.

PRE-TREATMENT:

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

Step 1 - Cleaning- We cleaned them in different ways:

a) using industrial dishwashers at restaurants at 60 degrees.

b) using a consumer home dishwasher

c) using a bathtub

d) by hand with a towel.

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, melting them is not necessary, with a minimum of 60 degrees this cleaning method is effective to remove all of the previous 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.

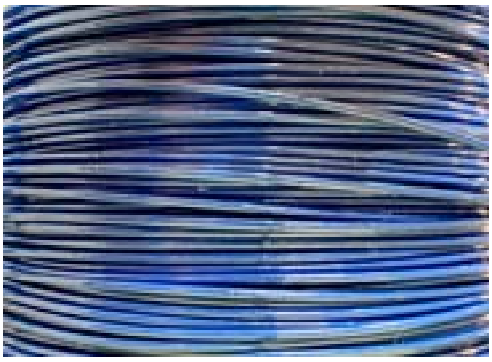
Step 2- Drying the wet cups and trays - Having liquids in the plastic could damage the shredder machine because of rust and it is also not ideal to have moist flakes for the filament making process.

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. As a result, the process takes longer and the machines cannot be fed too many objects at the same time, filling the hopper with bakjes is too much, instead you should feed in a few every few seconds after the previous have been shredded. Throwing too much into the shredder at once, would cause the shredder to stop due to accumulated material inside the granulator chamber.

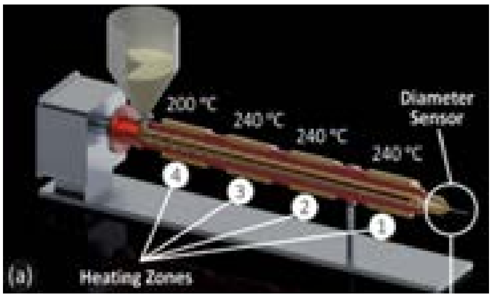
| Picture 3, Picture 4

Step 4- Drying the flakes -Using a flake/granulate dryer we, dry the shredded plastic to remove moisture content from the plastic. We dry it for 6 hours at 150 degrees. This releases trapped moisture that the plastic absorbs since it has hygroscopic properties.

CREATING A SPOOL



Picture 5: A good example of spooled filament made with Koppert Cress PET flakes



Picture 6: 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

At OurkilO, we aimed to produce a good spool. Our definition of a good spool is above 300g in a single roll. Next to that, it should have a consistent diameter throughout the whole length of the spool, never going above 1.9mm or below 1.6mm.

| Picture 5

The shredded plastic was processed in our designated PET filament maker machine at the following temperatures:

H4- 245° H3- 248° H2- 253° H1- 252°

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 6

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, and the strands of filament would come out flat and tiny which do not feed well into the printers.

CREATING A SPOOL

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

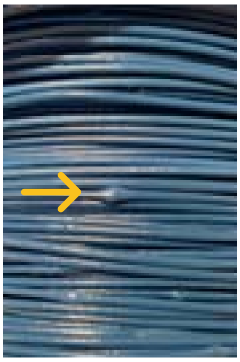
2) Adding 20% of PETG granules to the mixture of PET flakes.

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

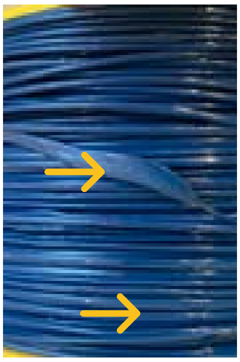
This is done to increase the volume of plastic inside the machine and to help with the feeding of plastic. The round shape of the granules is easier to fall down into the hopper of the filament maker. Thus, adding granules to the flakes prevents them from grabbing onto each other and creating a hole 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 10: Close-up of spools.



Picture 11: Very noticeable piece of contamination inside the filament as well as milky look meaning it is brittle.



Picture 12: A bad example of spooled filament. You can see a big blob of contamination in the middle of the spool, as well as other inconsistencies in the filament.

Picture 13: Spooled filament with consistent diameter and perfectly aligned in contrast to the errors showed above.

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. This is because PET flows much slower than PLA, meaning the machine has to run for longer to get to the same length. Also, PET is much more hygroscopic than PLA meaning it absorbs moisture and 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.

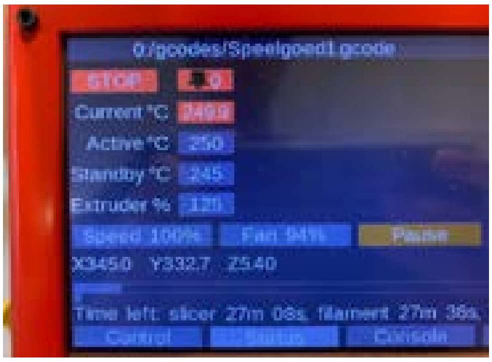
| Picture 10

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 11, Picture 12, Picture 13

PRINTING WITH RECYCLED RPET



Picture 14: Example of printing settings using a recycled spool.

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

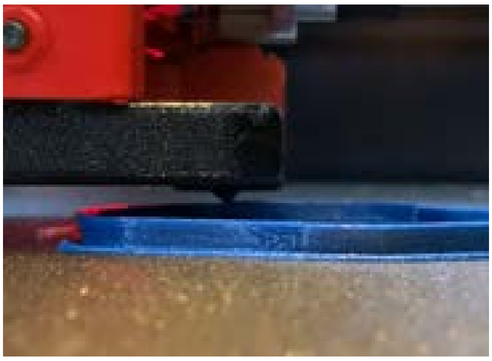
That is to achieve a chunky look but also to avoid impurities from clogging the nozzle. Clogging is a physical constraint, meaning either the filament was too thick to go through the heating element or there is a piece of alien material that does not melt and now is stuck inside the nozzle. A bigger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

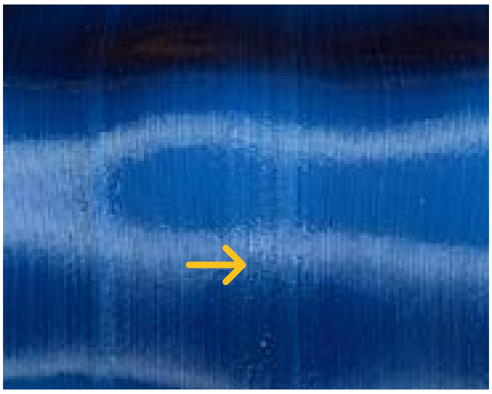
Picture 14

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 15: A chunky look is achieved with a bigger diameter nozzle.



Picture 16: picture showing two lines with diameter inconsistency in the filament, causing over-extrusion and undercooling.

Picture 17: Printing with a spool that contained too much humidity, as well as contamination from other plastics, thus causing the white specks.

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 clogging: When printing with our spools, we observe that it is common to have a clog just before the filament gets into the nozzle. This happens because occasionally the filament gets too thick and cannot be pushed through into the nozzle. It 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. We noticed that 30 minute prints are the best size to avoid stoppages.

Picture 16

2) Print Quality-Crystallization and Cooling issues: Our PET plastic is good for printing simple shapes, usually printing spirally. This is because

quick and short movements cause the crystallization of the material. The nozzle moving quickly close to itself causes the plastic to either not cool completely, or to cool 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 leading to crystalization.

3) Contamination-We noticed that the machine has to be fully cleaned of PET to prevent damage from crystalization. Since this has to be done before and after every material test the transition period from using DevoClean or HDPE plastics can cause unwanted mixing with PET. This means that parts of the filament can have strands of molten HDPE in the middle or DevoClean blobs of plastic making the filament bubbly.

Picture 17

The PET collected from Koppert Cress was a successful attempt at

CONCLUSION

Picture 18: The different range of 3D printed products with PET plastic, from decorative to useable in daily tasks.

Picture 19: PET is flexible which allows us to print tiewraps.

transforming waste plastic into a 3D printing filament. However, we learned that each batch of PET plastic has different properties and qualities. From our testing, we noticed that the PET from blue cups with lots of effort was useable as a 3D-printing filament plastic. However, the transparent trays were not able to be transformed into filament. This could be due to the vacuum-forming process and how that changes the reaction of the material to heat. We have observed similar results with other transparent vacuum formed PET in the consumer household testing we conducted.

Using the blue flakes of PET gave the filament a glossy-blue look or a rough-blue appearance. This was depending on the temperature. the filament could be strong and useable when using the right print settings, but also with the possibility to malleable to use with light flexible parts. Durability is affected if the spools are not stored correctly. This material specifically was very prone to absorb moisture, requiring a special way to store it. We found out that if the spool was left outside a vacuum sealed bag for 3 days, it would absorb too much moisture causing bubbles when printing.

MORE INFORMATION