3devo

MATERIALS MADE **SIMPLE**.

RECYCLING **PS** SPOOLS

Making a spool of spools

3devo’s experience with the recycling of spools which hold 3D printing filament, made of a grade of Polystyrene (PS). The material will be referred to as “PS” in this report.

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TABLE OF

CONTENTS

WHAT TO DO WITH PS SPOOLS?

PS spools are, to a certain extent, overlooked waste material of FDM printing. While offering interesting mechanical properties, it can be said that PS spools are abundant wherever filament is present. Surprisingly, filament of great quality can be obtained out of those omnipresent spools. Let's make a "spool of spools".

1. INTRODUCTION AND CONTEXT OF THIS REPORT

This document guides the reader through the recycling process of PS, performed in our test lab at 3devo. It describes the experimental process that led to the optimal settings and the best product quality.

The goal of the test was to extrude filament of **1.75 mm** thickness out of PS regrind. Figure 1 is a picture of the regrind, which was obtained by shredding spools using our Shr3d It (shown in Figure 2).

Chapters 2 to 5 explain more in detail the main experimental steps of the extrusion test, which consisted in a series of adjustments. The extrusion test was performed on a **Precision Filament Maker** equipped with a **4 mm nozzle**. Chapter 6 gives an overall conclusion regarding the recyclability of PS, and summarizes the entire report.

Figure 1 - *PS regrind in the jar, original spools behind it*

Figure 2 - *Picture of the SHR3D IT - Shredder used to shred the spools*

Figure 3 - *Feeding PS into the hopper of the extruder*

2. PREPARATION AND PRE-PROCESSING

The material was obtained in the form of used spools which were unprotected from moisture for several weeks. However, drying is typically not required for PS-based formulations, because PS is a hydrophobic material.

Before the extrusion test, the machine was purged with the following compounds:

- Devoclean MidTemp at 210˚C
- HDPE at 210˚C (this step is not mandatory but can accelerate the transition to PS a bit)

PS was then introduced at 210˚C.

WARNING *When experimenting with a new grade of plastic, it is of the utmost importance to introduce said plastic at temperatures high enough to ensure sufficient melting and to avoid the clogging of the machine.*

Figure 3 is a picture of the material in the hopper.

3. EXTRUSION (1): STARTING POINT AND FIRST OBSERVATIONS

The following settings were used as a starting point during the extrusion test:

Parameter	H4	H3	H2	H1	Screw speed	Fan speed
Set value	210 °C	210 °C	210 °C	210 °C	5.0 RPM	50%

WHY 210˚C? As mentioned earlier, it is wiser to start at a temperature that is too high, to avoid the clogging of the machine. For most grades of PS, 210°C is on the high end of the thermal window of operation.

WHY 5.0RPM AND 50% FAN SPEED? These values are very often appropriate values to start experimenting with a new material. In order to extrude stable filament of 1.75mm thickness, the best rotation speed is usually found between 3.0 and 6.0 RPM, which is why the starting value of 5.0RPM is always a good start. As far as the fan speed is concerned, it is harder to define an ideal percentage that works by default, because this parameter can vary a lot; it is good to start with a medium value and be ready to make quick adjustments.

THE FIRST RESULTS: The transition from HDPE to PS was fast (a few minutes). The flow appeared to be rather stable, the extrudate was fully molten and free of impurities and bubbles. The extrudate was too liquid when reaching the puller and therefore flattened by it. Figure 4 is a picture of the first results, before the filament was properly placed in the filament sensor.

Figure 4 - *First PS output obtained at high RPM (to speed up the transition process)*

4. EXTRUSION (2): AJUSTMENT STEPS

The objective was to find the optimal extrusion settings with the help of the filament sensor. Because the flow was very stable, the challenge was to make sure the extrudate was fully solidified before reaching the puller, without disturbing the flow or creating instabilities. Figure 5 is a picture taken during the adjustment phase, before the filament was of sufficient quality to be spooled. Figure 6 shows a number of samples, to illustrate how the filament was controlling the diameter of the product by adjusting the speed of the puller (to elongate the output more or less based on the thickness readings).

FILAMENT FAN SPEED: It was found that to achieve optimal quality, a high fan speed was preferred, around 100%.

SCREW RPM: In order to maintain a steady flow and just enough pressure inside the barrel, without affecting the initial good results too much, the solution was to decrease the screw speed slightly, to 4.5RPM. This way, the extrudate was given additional time to be cooled down by the fans.

TEMPERATURES: When working with PS, it is crucial to keep the temperatures high enough to avoid any clogging. Knowing this, the temperatures were lowered slightly by 5°C to 10°C, to allow the filament to be cooled down a little more easily. Using an ascending thermal profile (200°C to 210°C) also increases the stability of the flow, allowing for a gradual building-up of the pressure inside the barrel.

Figure 5 - *Filament flowing freely during the adjustment phase*

Figure 6 - *Filament thickness controlled by the filament sensor: thinner and thinner down to the desired thickness (top to bottom)*

5. EXTRUSION (3): SPOOLING

The filament was spooled using the final settings found during the adjustment phase:

Parameter	H4	H3	H2	H1	Screw speed	Fan speed
Set value	200 °C	205 °C	210 °C	210 °C	4.5 RPM	100%

A spool was successfully manufactured using these settings

Figure 7 is the graphical representation of the datalog which corresponds to the produced spool. It shows that the filament thickness was extremely stable during the entire spooling process. The filament is well kept within the usual industry tolerance (1.75±0.05mm), over a long time.

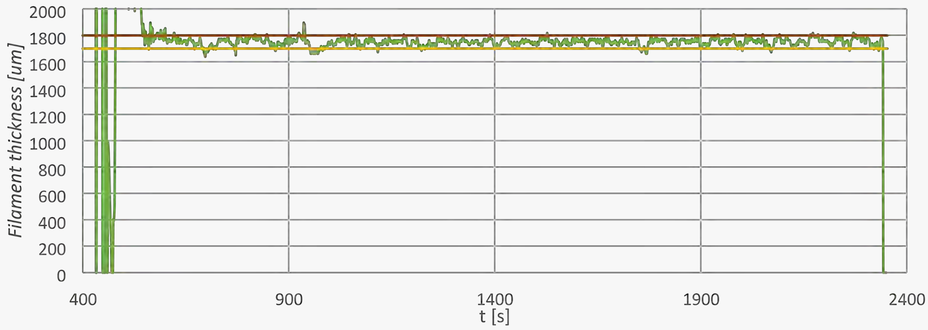

Figure 7 - *Datalog : filament thickness (set value : 1.75mm, red line : 1.80mm, yellow line : 1.70mm)*

***Figure 8 -** Initial spool of PS (bottom), jar of PS regrind (center), spooled recycled PS*

6. CONCLUSION AND RECOMMENDATIONS

This extrusion experiment was extremely positive. Indeed, 1.75mm filament of excellent quality was obtained using a Precision equipped with a 4mm nozzle. The final spool is visible in Figure 8. Even though the 3D printing of this filament remains to be investigated, it can be said that the material could be extruded quite easily, without facing any major issue, and that the resulting filament's thickness was well-kept within industry tolerance standards (+/- 50 microns).

REPORT SUMMARY:

TO DOs:

- Keep temperatures around 205°C for optimal quality
- Purge thoroughly before and after the extrusion
- To start extruding PS, start by purging at 205°C with Devoclean MidTemp
- At the end of the extrusion, transition back to Devoclean MidTemp (at processing temperatures)

WARNINGS:

- It might be necessary to adjust the fan speed around 100% depending on the room conditions
- If 100% of cooling do not suffice (filament flattened by the puller), decrease the screw speed slightly, down to 4.3RPM for example
- Do not leave any trace of PS inside the machine over a shutdown period. Only Devoclean MidTemp can be left inside a cold machine.

Parameter	H4	H3	H2	H1	Screw speed	Fan speed
Set value	200 °C	205 °C	210 °C	210 °C	4.5 RPM	100%