MATERIALS MADE **SIMPLE**.

RECYCLING **TPE** INJECTED WASTE

Shredding and Extrusion Walkthrough

Our experiences with the shredding and extrusion of Evoprene® G972 injected waste and pellets. The material will be referred to as “SEBS” in this report, since it is a grade of fully saturated styrene ethylene butylene styrene copolymer.

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SEBS IN A NUTSHELL

- *Opaque and black*
- *Combines rubbery properties of elastomers and processing properties (suitability for extrusion) of thermoplastics*
- *Good resistance against UV, ageing, chemical agents (including acids)*
- *Rather low heat resistance (typical processing temperatures around 180˚C and maximum usage temperature around 120˚C)*

1. INTRODUCTION AND CONTEXT OF THIS REPORT

This document guides the reader through the shredding process and extrusion process of SEBS pellets and injected waste, 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 recycle parts of various shapes made of injected SEBS, and also process virgin SEBS pellets into **1.75mm filament.** Figure 1 is a picture of the original pellets provided in a sealed plastic bag.

Chapter 2 describes the shredding step prior to extrusion. Chapters 3 to 6 explain more in detail the main experimental steps of the extrusion test itself, which consisted in a series of adjustments. These chapters apply to both pristine SEBS pellets and recycled SEBS because the settings used were identical. It is crucial to note that the extrusion test was performed on a **Precision** machine equipped with a **2mm nozzle.** Chapter 7 gives an overall conclusion regarding the processability and recyclability of SEBS, and summarizes the entire report.

***Figure 1 -** Batch of pristine SEBS pellets*

***Figure 2 -** Picture of the SHR3D IT - Shredder*

2. SHREDDING

The shredding step was performed on the SHR3D IT (shown in Figure 2) equipped with a 4mm particle filter. This operation was rather straightforward, the injected parts being quite flexible and easily fed in the shredder.

Feeding of the shredder was then very easy, and the shredding process quickly gave good results. Figure 3 is a picture of the feeding step, which shows that the parts were flexible enough to be fed in the hopper of the shredder. The parts were also mechanically cohesive enough, because of there rubbery-like behavior, to be shredded without any difficulty and without the need for manual force-feeding. In other terms, when the tip of a part was caught by the first teeth of the machine, the rest of the part was then gradually shredded without any trouble.

Figure 3 - *Feeding the SHR3D IT*

Figure 4 is a picture of the first sample of regrind that was obtained after a few moments of shredding.

Figure 4 - *a picture of the first sample of regrind that was obtained after a few moments of shredding.*

Figure 5 - *Size and shape comparison between SEBS regrind (left) and standard PLA pellets (right)*

Figure 5 is a picture meant to compare the shape and size of the SEBS regrind and standard Polylactic Acid (PLA) pellets commonly used in extrusion for good quality results. It can be seen that the particle size distribution of the regrind is rather narrow, and that the particle size is similar or inferior to standard PLA pellets, which is a first indication that the plastic will feed and melt easily in the extruder. Figure 6 shows that the whole batch of regrind looks homogeneous and free of significant impurities.

Figure 6 - *Whole batch of SEBS regrind stored in a jar*

3. PREPARATION AND PRE-PROCESSING

The material was supplied in a sealed plastic bag, protected from dust but not from moisture. However, this was not an issue because drying is typically not required for SEBS.

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

- Devoclean MidTemp to clean the barrel thoroughly
- HDPE to transition more easily to PLA
- PLA to transition more easily to SEBS

This purging/transitioning process was done at 185˚C (all four heaters). Figure 7 displays samples of all three purging/transitioning compounds, as well as the jar of SEBS regrind. SEBS was then introduced at 185˚C.

Figure 7 - *Materials samples : (from left to right) Devoclean MidTemp, HDPE, PLA, SEBS regrind*

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 8 is a picture of the feeding, Figure 9 illustrates the transition from PLA to SEBS. The transition only took a few moments, it was sudden and clearly visible.

Figure 8 - *Feeding SEBS regrind into the hopper of the extruder*

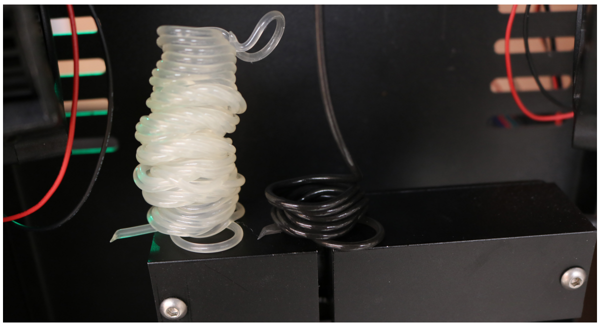

Figure 9- *Transition from purging PLA (transparent extrudate on the left) to SEBS (black opaque extrudate on the right, still containing a small fraction of PLA). Only a few seconds and a small piece of extrudate are missing on the picture, between the PLA and the SEBS displayed on the picture.*

4. 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	185 °C	185 °C	185 °C	185 °C	5.0 RPM	50%

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 around 3.0 to 5.0 RPM, with rare exceptions up to 7.0RPM; this 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 PLA was smooth and fast, the flow did not seem to be much disturbed. The flow appeared to be extremely stable.

THE ISSUE: It was found that the extrudate was too hot when reaching the puller : it was too liquid, therefore crushed by the force of the puller wheels, and too sticky, impeding proper pulling.

5. EXTRUSION (2): AJUSTMENT STEPS

The objective was to find the optimal extrusion settings with the help of the filament sensor. The main issue was that the extrudate was too hot, resulting in the flattening of the filament by the puller wheels. Figure 10 and Figure 11 were taken toward the end of the adjustment phase.

FILAMENT FAN SPEED: Because the extrudate was too hot when reaching the puller, the correct and obvious approach was to increase the fan cooling percentage to **100%.**

SCREW RPM: The screw rotation speed was decreased gradually down to **2.8RPM.** Despite the high filament fan speed, it was found that screw speeds of 4.0RPM, 3.5RPM, and 3.0RPM, were slightly too fast, resulting in the partial flattening of the filament by the puller wheels into an oval-shaped filament. Decreasing the screw speed helped to cool down the filament since a slower output spends more time being cooled down, traveling from the nozzle to the puller at lower speed.

TEMPERATURES: Because the flow was extremely stable, only the last temperature along the barrel (**H1**) was decreased slightly, down to **178°C**. By leaving the other temperatures unchanged, the quality of the flow was preserved and the extrudate was a little less liquid when exiting the nozzle.

RECYCLED SEBS VS PRISTINE SEBS: It was found that both virgin SEBS pellets and SEBS regrind had a very similar behavior : the same settings were used to spool both materials.

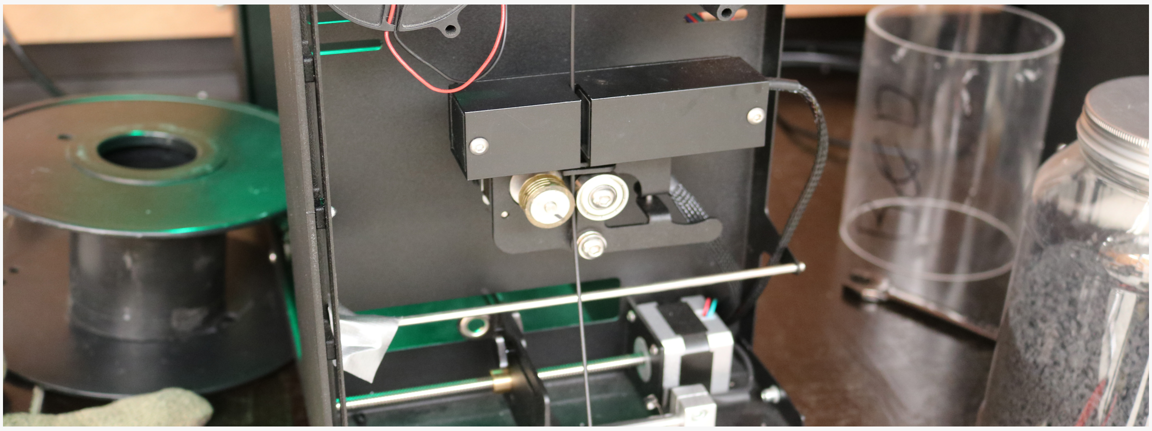

Figure 10- *Filament flowing freely during the adjustment phase*

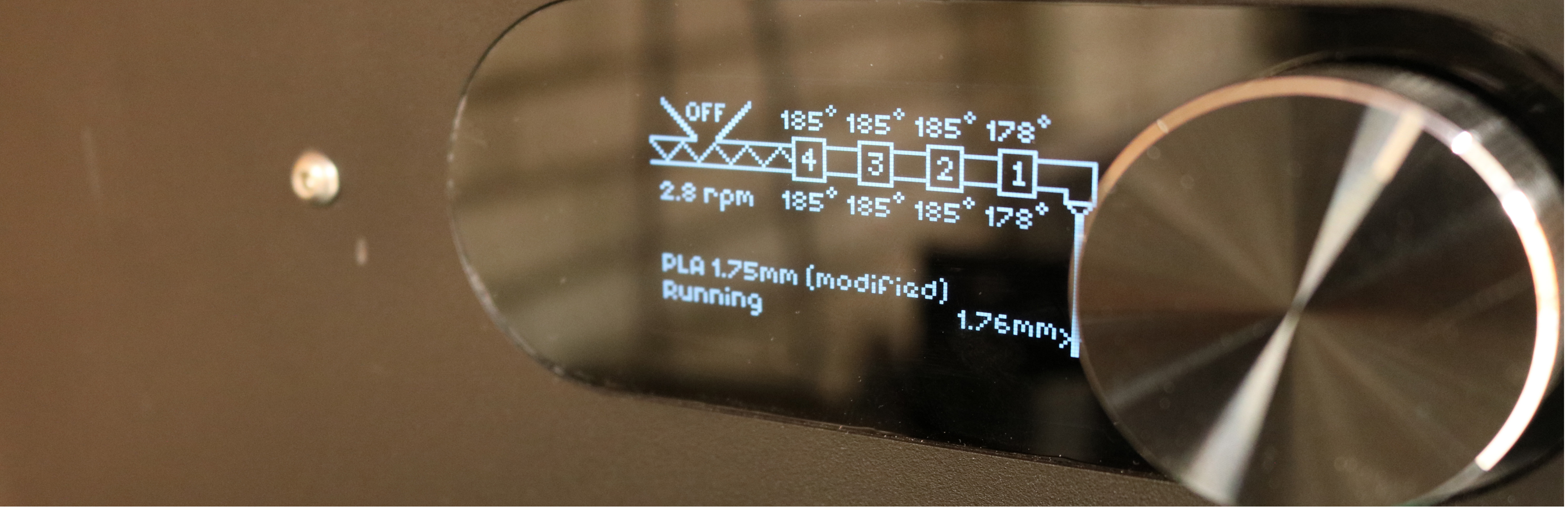

Figure 11 - *Final settings (as described in Chapter 6), set filament thickness 1.75mm*

6. 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	185 °C	185 °C	185 °C	178 °C	2.8 RPM	100%

Two spools were successfully manufactured using these settings : one spool of SEBS and one spool of recycled SEBS obtained directly by reprocessing injected waste. Figure 12 is a close-up view on the final products, which shows that the surface of the filament, upon looking extremely closely, is not fully smooth, because of the rubbery nature of the material. It seems that the product can catch dust from the room quite easily. Appropriate protective storage conditions should preserve the filament from dust contamination.

Figure 12 - *Microscope shot, slight roughness on the surface of the filaments (recycled SEBS on the top, pristine SEBS on the bottom)*

Figure 13 is the graphical representation of the datalog which corresponds to both of the extruded spools (spool of recycled SEBS starts at 500s, spool of pristine SEBS starts at 8500s approximately). It shows that the filament thickness was very stable during the entire spooling process, well kept within the usual industry tolerance (1.75±0.05mm).

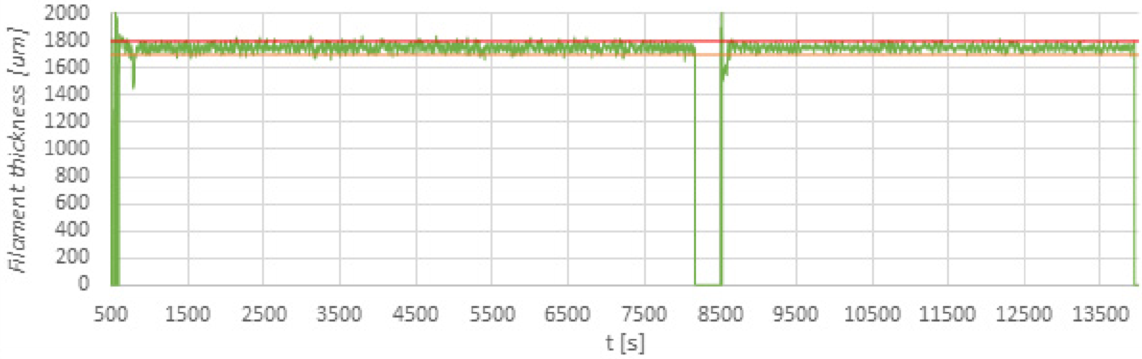

Figure 13 - *Datalog: filament thickness (set value: 1.75mm, red line: 1.80mm, orange line: 1.70mm)*

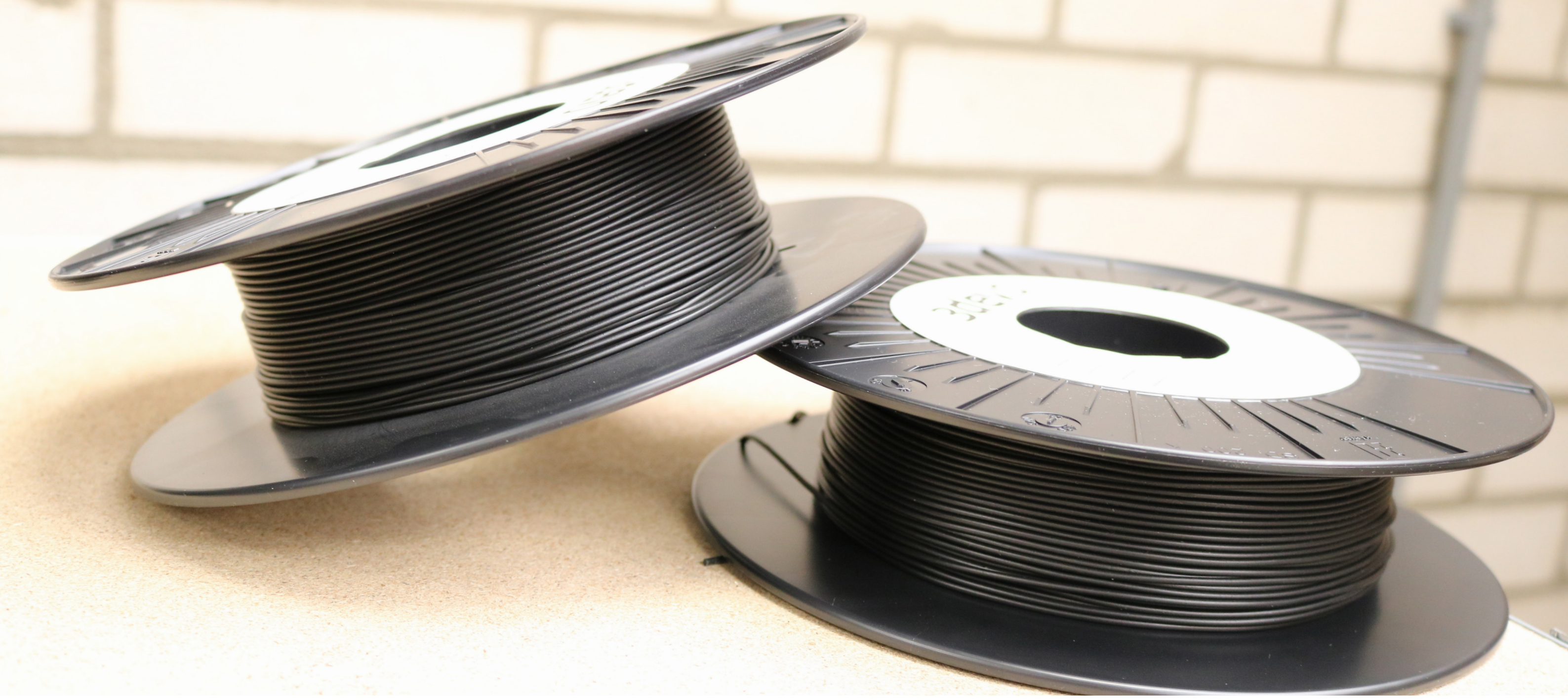

Figure 14 - *Spools of pristine SEBS (left) and recycled SEBS (right), both of great visual quality and tight tolerance*

7. CONCLUSION AND RECOMMENDATIONS

This extrusion experiment was extremely positive. Indeed, 1.75mm filament of great quality was obtained using a Precision equipped with a 2mm nozzle. New pristine pellets of SEBS could be processed without any difficulty, and injected waste could also be shredded and extruded into filament of great quality. Even though the 3D printing of these filaments remains to be investigated in order to close the loop and print parts of excellent quality, it can be said that the material can be shredded and extruded very easily, without facing any major issue, and that the resulting filament's thickness is well-kept within industry tolerance standards (+/- 50 microns). The fact that the material could be processed at relatively low temperatures made the launching of the process a fast operation, but the purging was more tedious because of the strong black color of the formulation. Figure 14 is a picture of the two spools which were obtained at 3devo in one day of testing.

REPORT SUMMARY:

TO DOs:

- Easy shredding of the material due to the rubbery nature of the parts
- Keep temperatures around 185°C for optimal quality
- High fan speed (100%) is necessary

WARNINGS:

- Use the shredder and the extruder with great care, blades and heat are involved
- Watch out for impurities (dust mostly) during shredding and storage
- If you try to increase the flow (production rate), gradually increase the RPM by very small steps and make sure the filament does not become sticky/liquid when reaching the puller. Decreasing the temperatures (especially H1) might help cool down the filament enough.
- Purge **thoroughly** after extrusion using Devoclean MidTemp at 185°C (all heaters)
- Transition back to SEBS with HDPE, then PLA (at 185°C). This is not mandatory but will save some SEBS.

Parameter	H4	H3	H2	H1	Screw speed	Fan speed
Set value	185 °C	185 °C	185 °C	178 °C	2.8 RPM	100%