



3devo

MATERIALS MADE **SIMPLE.**

MAKING PHB FILAMENT

Extrusion Walkthrough

Our experiences with the extrusion of Aldrich, a grade of Poly[(R)-3-hydroxybutyric acid (PHB). The material will be referred to as “PHB” in this report.

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Figure 1 - Batch of PHB pellets

1. INTRODUCTION AND CONTEXT OF THIS REPORT

This document guides the reader through the extrusion process of PHB, 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 PHB pellets into **1.75mm filament**. Figure 1 is a picture of the original batch of pellets already loaded into our extruder.

Chapters 2 to 5 explain more in detail the main experimental steps of the extrusion test itself, which consisted in a series of adjustments. It is crucial to note that the extrusion test was performed on a **Precision** machine equipped with a **4mm nozzle**. Chapter 6 gives an overall conclusion regarding the processability of PHB, and summarizes the entire report.

Figure 2 - Picture of the Airid Polymer Dryer in action



Figure 3 - Feeding PHB regrind into the hopper of the extruder



2. PREPARATION AND PRE-PROCESSING

The material was supplied in a plastic bag, unprotected from moisture. The drying was performed at **80°C for 2 hours** in our Airid Polymer Dryer, as shown in Figure 2.

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 PHB

This purging/transitioning process was performed at 200°C (all four heaters).

PHB was then introduced at 200°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 feeding.

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	200°C	200 °C	200 °C	200 °C	5.0 RPM	50%

WHY 200°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 PHB, the low degradation point is 220°C

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 7.0 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 was smooth and fast, Figure 4 illustrates the transition from HDPE to PHB. The transition only took a few moments, it was sudden and clearly visible. The flow did not seem to be much disturbed. The flow appeared to be stable.

4. 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 5 is a picture taken during the adjustment phase, before the filament was of sufficient quality to be spooled.

FILAMENT FAN SPEED : Because the extrudate was too hot when reaching the puller, the correct approach was to increase the fan cooling percentage and to add a circular cooling accessory. Several options were tested between 70% and 100%. 80% resulted in the best pliable but stiff filament for the adjustment phase of the puller wheel.

TEMPERATURES : All temperatures were decreased gradually, 5°C by 5°C, down to 155-185°C

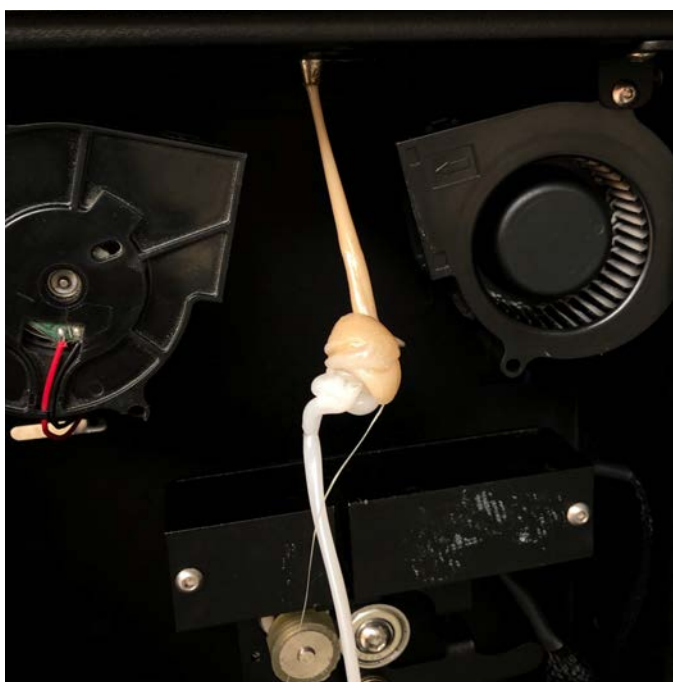


Figure 4 - Transition from purging HDPE (white extrudate at the bottom) to PHB (yellow extrudate at the top)

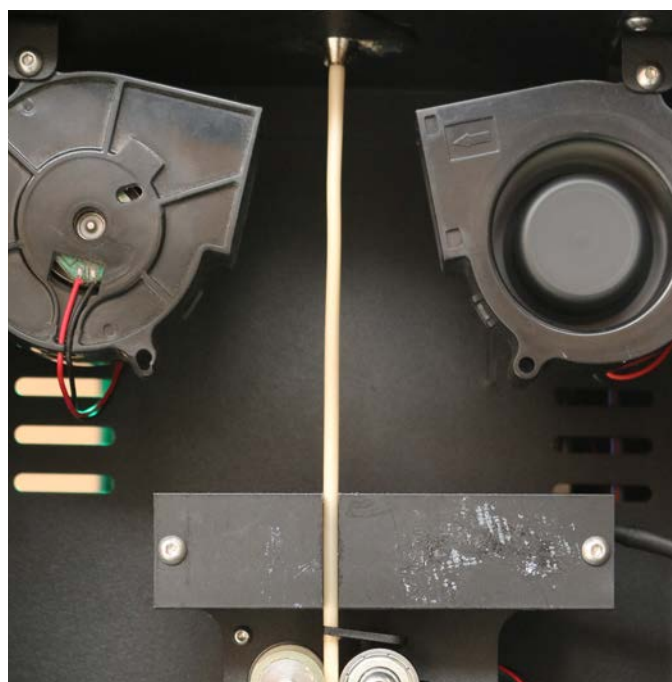


Figure 5 - Filament flowing freely during the adjustment phase

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	165°C	175 °C	185 °C	165 °C	3.5 RPM	80%

A spool was successfully manufactured using these settings. Figure 6 is the graphical representation of the datalog which corresponds to the produced spool. It shows that the filament thickness was very stable during the entire spooling process, rather kept within the usual industry tolerance ($1.75 \pm 0.05\text{mm}$).

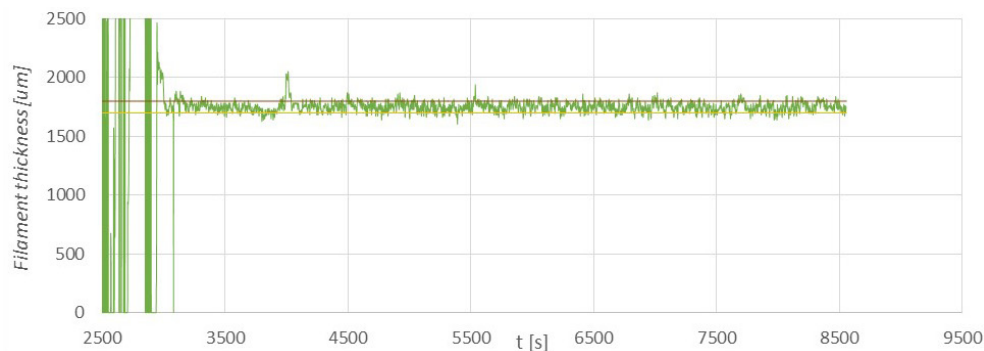


Figure 6 - Datalog: filament thickness (set value : 1.75mm, red line : 1.80mm, yellow line : 1.70mm)

6. CONCLUSION AND RECOMMENDATIONS

This extrusion experiment was extremely positive. Indeed, 1.75mm filament of great quality was obtained using a Precision equipped with a 4mm nozzle. Even though the 3D printing of this filament remains to be investigated, it can be said that the material can be extruded easily, without facing any major issue, and that the resulting filament's thickness is nearly within industry tolerance standards (± 50 microns).

REPORT SUMMARY:

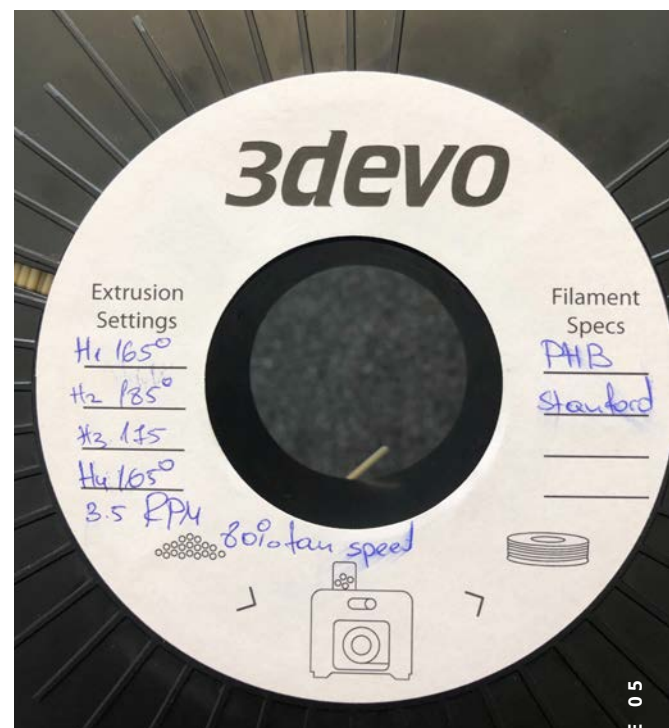
TO DOs:

- Keep temperatures around 165-185°C for optimal quality
- Dry the material at 80°C for at least 2h in a dryer or an oven if needed
- Purge thoroughly after extrusion using first HDPE and then Devoclean MidTemp (while climbing in temperatures up to 250°C) when finishing the extrusion. Follow the same steps from DevoClean to HDPE and lower the temperature to 200°C when first switching to PHB

WARNINGS:

- It might be necessary to adjust the fan speed depending on the room conditions
- Do not leave any trace of PHB inside the machine over a shutdown period. Only Devoclean MidTemp and HDPE can be left inside a cold machine.

Figure 7 - Spool of PHB



Parameter	H4	H3	H2	H1	Screw speed	Fan speed
Set value	165°C	175 °C	185 °C	165 °C	3.5 RPM	80%