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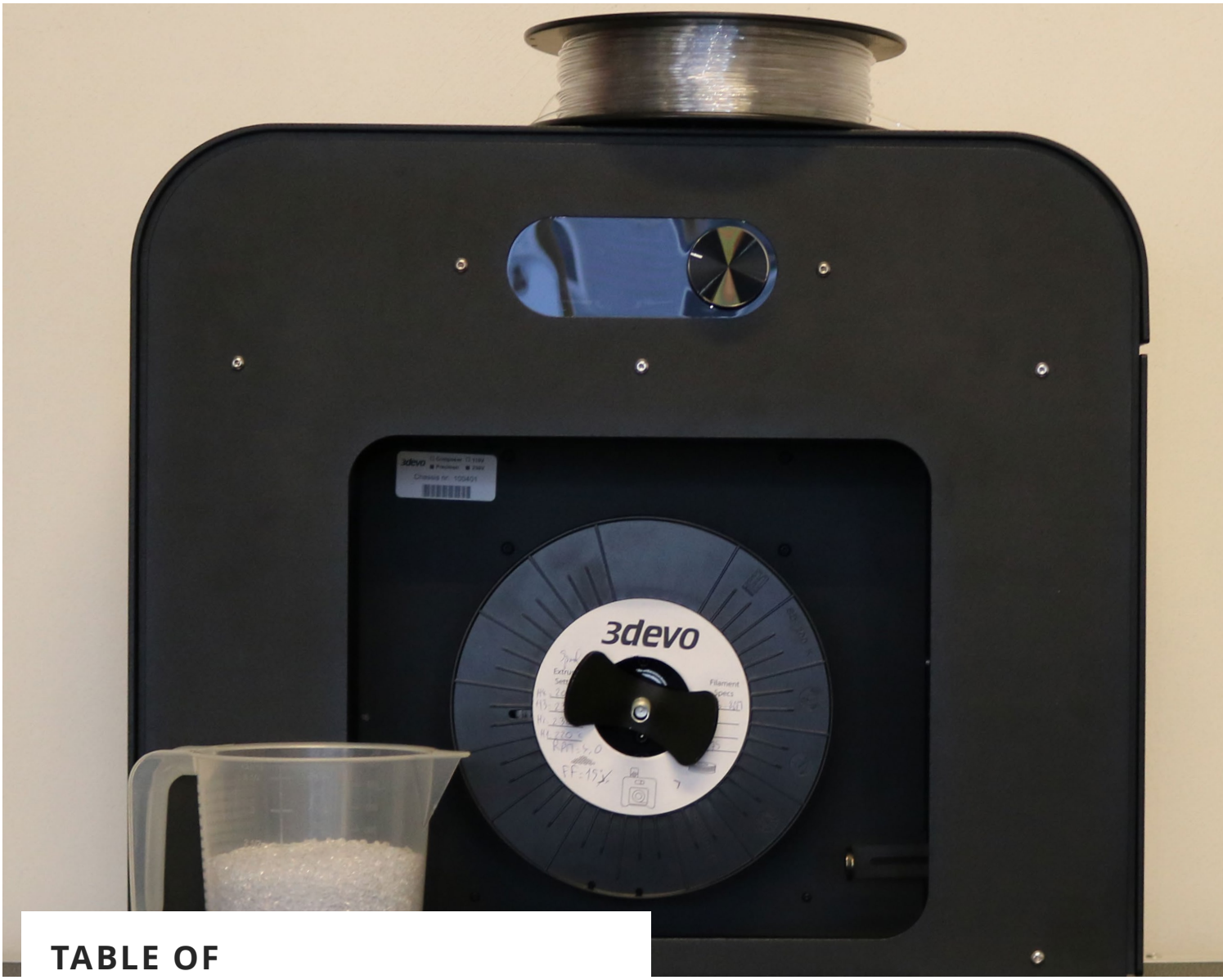
MATERIALS MADE **SIMPLE**.

PETG Genius 80M

Extrusion Walkthrough

Our experiences with the extrusion of PETG Genius 80M, a grade of Polyethylene Terephthalate Glycol (PETG). The material will be referred to as “PETG” in this report.

DATE: JULY 2, 2019



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PETG IN A NUTSHELL

- *Transparent, colorless, optical clarity, glossy surface*
- *Amorphous, does not crystallize*
- *Widely used filament, alongside PLA and ABS, easy to print*
- *Durable, quite soft and ductile*

1. INTRODUCTION AND CONTEXT OF THIS REPORT

This document guides the reader through the extrusion process of PETG, 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 PETG pellets. Figure 1 is a picture of the original pellets.

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 processability of PETG, and summarizes the entire report.

Figure 1 - *Pellets of PETG*

Figure 2 - *Picture of the Dryer (the picture was not taken during this specific project)*

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

2. PREPARATION AND PRE-PROCESSING

The material was supplied in a plastic bag, unprotected from moisture. Drying is typically a crucial step when trying to process PETG-based formulations.

The **drying** was performed at **70°C for 4h** in our Dryer, as shown in Figure 2.

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

- Devoclean MidTemp at 260˚C
- HDPE at 260˚C

PETG was then introduced at 260˚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. A feeding issue was faced: PETG has the tendency to form lumps in the feed zone because it typically becomes sticky above 70 ˚C. The consequence is that the throat at the bottom of the hopper becomes partially clogged, unless the temperature of the feed zone is kept sufficiently low. The presence of lumps in the feed zone can lead to flow instabilities, or can even stop the flow of material in more extreme cases.
To solve this issue, it is important to set a lower temperature on the first heater. An extra fan can also be placed on the

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	260 °C	260 °C	260 °C	260 °C	5.0 RPM	50%

WHY 260°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 PETG, 260°C is on the high end of the thermal window of operation (230-270°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 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, illustrated in Figure 4, was not fast. The flow appeared to be rather stable, the extrudate was fully molten and free of impurities and bubbles. However the extrudate was white for more than 30min, as a result of a reaction between the transparent HDPE and the transparent PETG. It can be easily said when the transition is over because the extrudate then becomes transparent optically clear as PETG should be..

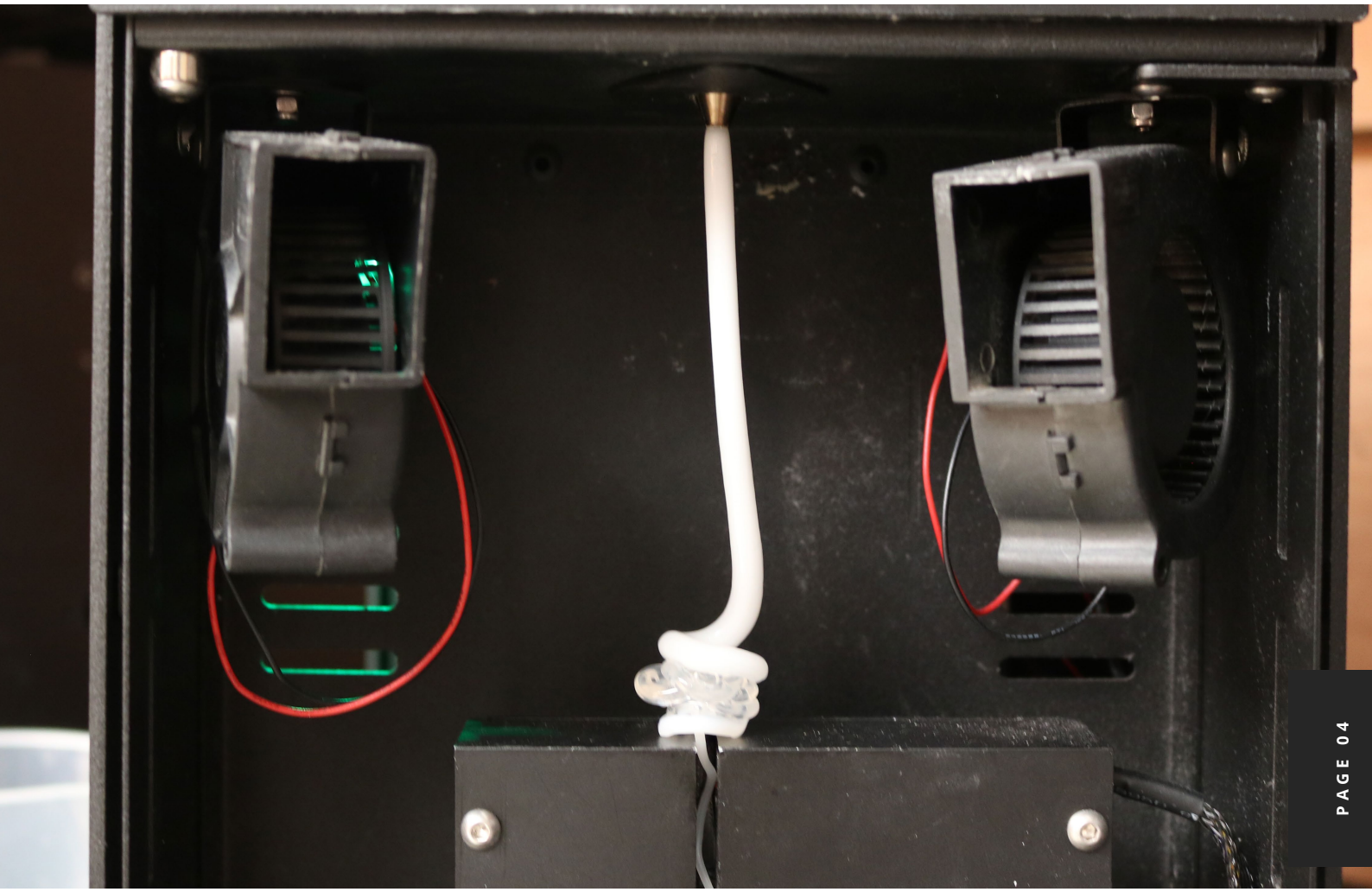

Figure 4 - *Transition from HDPE (white-transparent plastic at bottom) to PETG (not visible in its pure form, instead a white opaque output flows for a while)*

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 slightly unstable, the challenge was to make sure the pressure buildup was consistent inside the barrel. Figure 5 is a picture taken during the adjustment phase, before the filament was of sufficient quality to be spooled.

FILAMENT FAN SPEED : It was found that to achieve optimal quality, a high fan speed was preferred, around 90%.

SCREW RPM : In order to achieve a steady flow and maintain just enough pressure inside the barrel, the solution was to decrease the screw speed slightly, to 4.3RPM. This way, the rotation speed of the screw was fluctuating less and the extrudate was given additional time to be cooled down by the fans.

TEMPERATURES : When working with PETG, it is crucial to keep the temperatures high enough but lower in the feed zone, and make small adjustments at a time. In particular, H4 should be set around 220°C in combination with the extra fan blowing on the barrel. Because PETG is an amorphous material, a "low-high-low" thermal profile was set to increase the stability of the flow.

THE IMPORTANCE OF DRYING : Not drying the PETG may result in the presence of bubbles in the filament, that will dramatically damage the mechanical properties of the material, and increase fluctuations and inconsistencies in the flow.

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	220 °C	235 °C	230 °C	221 °C	4.3 RPM	90%

A spool was successfully manufactured using these settings. Figure 6 is a microscope shot of the product.

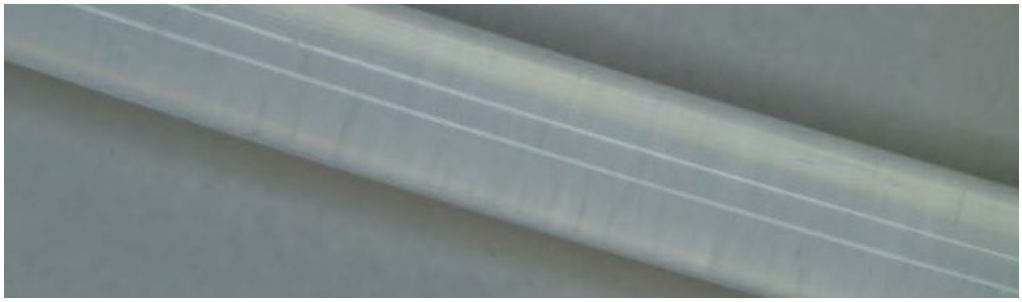

Figure 6 - *Microscope shot to show the visual aspect of the PETG filament : smooth, homogeneous, clear, consistent*

Figure 7 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. The filament was rather well kept within the usual industry tolerance (1.75±0.05mm), over a long time.

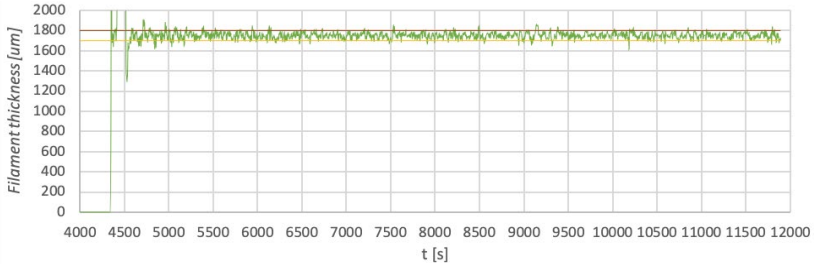

Figure 7 - *Datalog : filament thickness (set value : 1.75mm, red line : 1.80mm, yellow line : 1.70mm)*

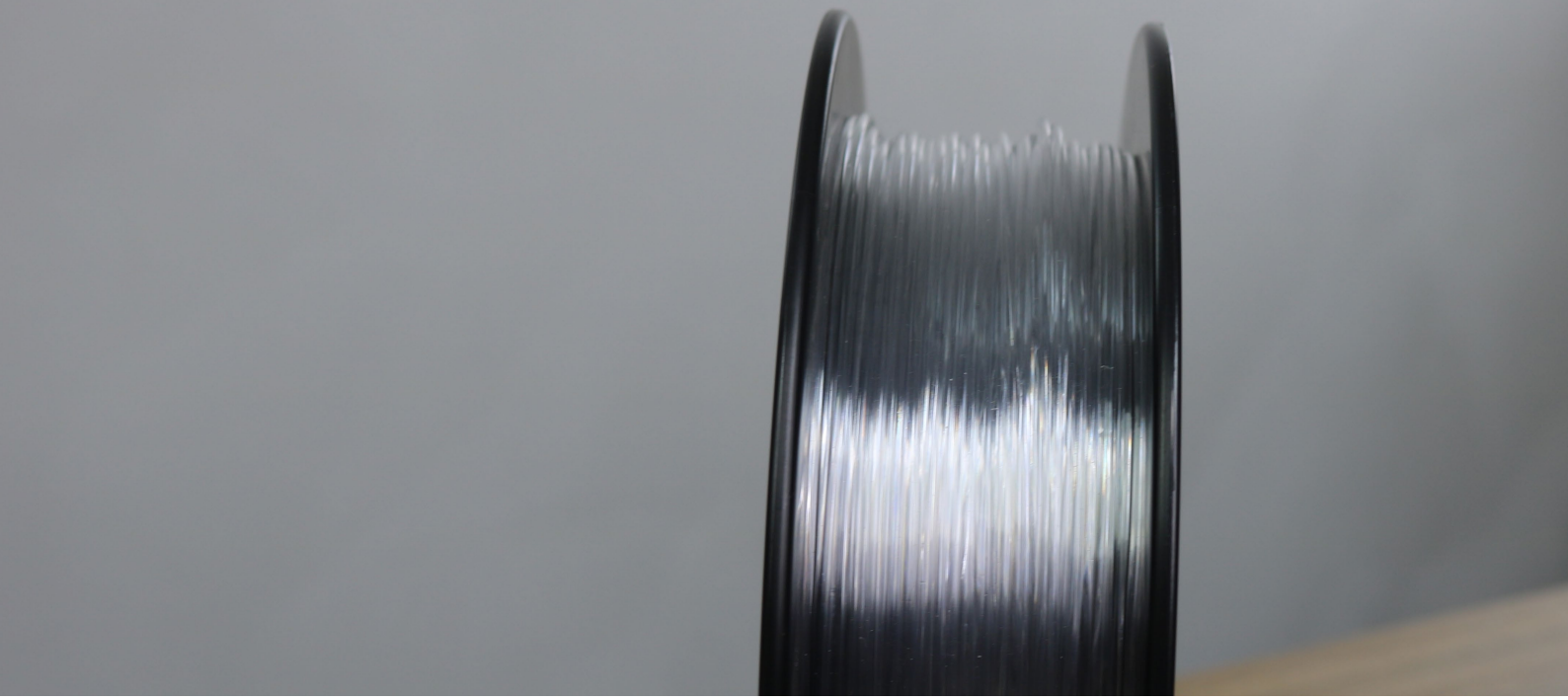

***Figure 8** - Spool of PETG*

6. CONCLUSION AND RECOMMENDATIONS

This extrusion experiment was extremely positive. Indeed, 1.75mm filament of good 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 quite well-kept within industry tolerance standards (+/- 50 microns).

REPORT SUMMARY:

TO DOs:

- Keep temperatures around 230°C for optimal quality
- Dry the material at 70°C for at least 3-4h in a dryer or an oven
- Purge thoroughly before and after the extrusion
- To start extruding PETG, start by purging at 240°C with HDPE, then introduce the PETG and immediately set the final settings and activate a fan on the feed zone
- At the end of the extrusion, purge the machine for a few minutes with Devoclean MidTemp

WARNINGS:

- It might be necessary to adjust the fan speed around 90% depending on the room conditions
- If lumps are being formed in the hopper, make sure the feed zone is cooled down by a lateral fan. It is also possible to decrease the temperature of H4.
- PETG should not be left inside the machine over a shutdown period: the purging step must be done carefully.
- The transition from HDPE to PETG typically takes 30min approximately, depending on the chosen screw speed

Parameter	H4	H3	H2	H1	Screw speed	Fan speed
Set value	220 °C	235 °C	230 °C	221 °C	4.3 RPM	90%