MATERIALS MADE **SIMPLE**.

ABS Magnum 3513

Extrusion Walkthrough

Our experiences with the extrusion of Magnum 3513, a grade of Acrylonitrile butadiene styrene (ABS). The material will be referred to as "ABS" in this report.

DATE: JULY 11, 2019

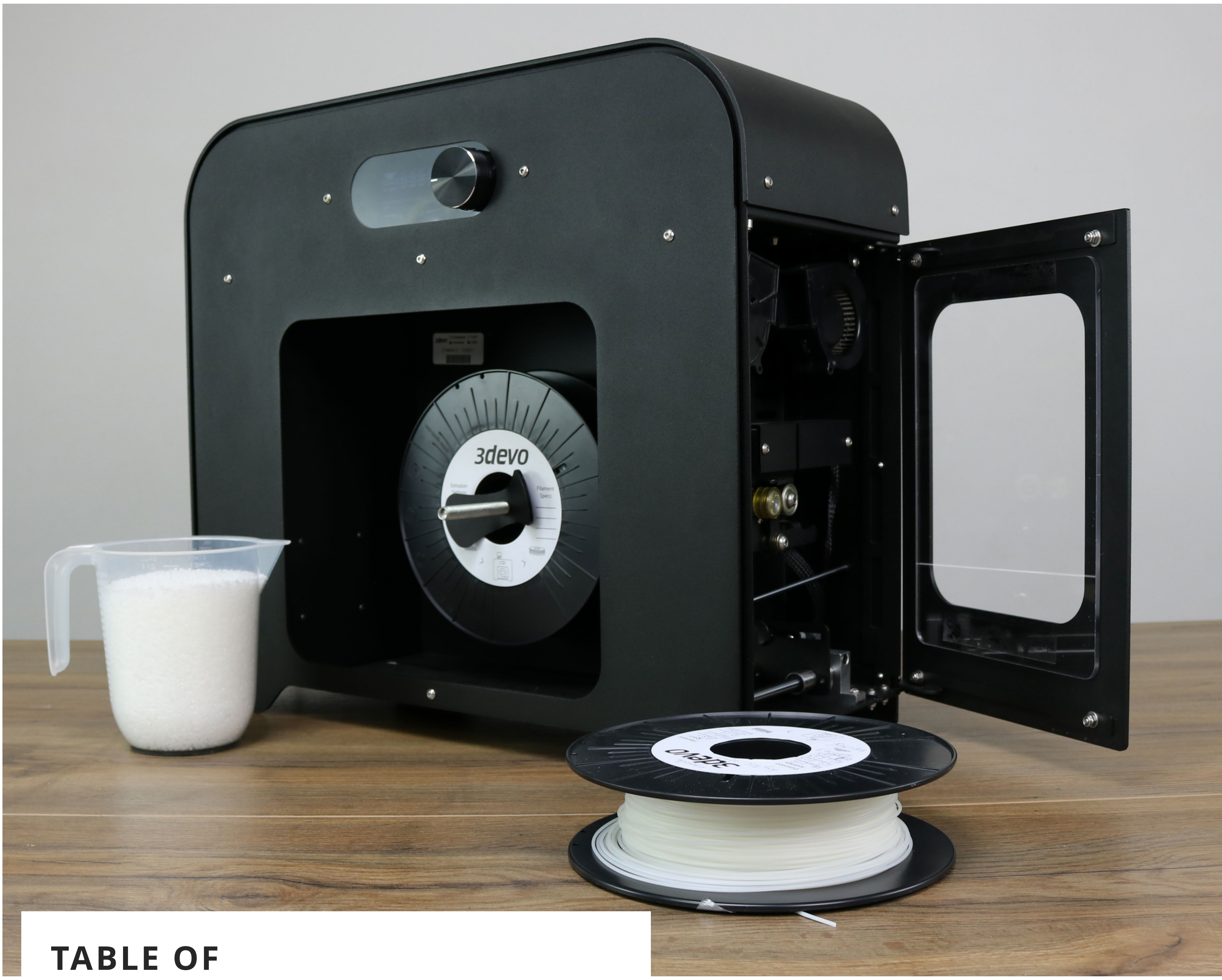

TABLE OF CONTENTS

ABS IN A NUTSHELL

- *Originally white and opaque*
- *After PLA the most commonly used 3D-printing material and fairly easy to print.*
- *Very high durability, relatively high temperature resistance and moderately flexible.*
- *Mainly used for high-wear components. A benefit of using ABS as a 3D-printing material is the fact that it can be treated with acetone to get a smoother surface.*

1. INTRODUCTION AND CONTEXT OF THIS REPORT

This document guides the reader through the extrusion process of ABS, performed in our test lab at 3devo. It describes the experimental process that led to the optimal settings and the best product quality. Please be aware that every grade of ABS behaves differently, so the process described here will probably not be 100% applicable to your material.

The goal of the test was to extrude pellets of ABS into **1.75mm filament.** Figure 1 is a picture of the original batch of pellets.

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 **2mm nozzle.** Chapter 6 gives an overall conclusion regarding the processability of ABS, and summarizes the entire report.

Figure 1 - *Batch of ABS pellets*

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 hygroscopic formulations such as ABS.

Since ABS does not absorb so much moisture as other hygroscopic materials such as Nylon, the **drying** was performed at **80°C** for only **1 hour** in our 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 ABS

This purging/transitioning process was performed at 240˚C (all four heaters).

ABS was then introduced at 240˚C (Figure 3).

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

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

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

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	240 °C	240 °C	240 °C	240 °C	5.0 RPM	50%

WHY 240˚C ? As mentioned earlier, it is wise to start at a temperature that is too high, to avoid clogging of the machine as a result of unmelted particles. For most grades of ABS, 240°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 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 ABS. The transition only took a few moments, it was sudden and clearly visible as the ABS is more opaque and white than HDPE.
The output flow did not seem to be much disturbed. The flow appeared to be rather stable but the extrudate was too liquid: it was hard to pull it properly because it was flattened by the puller and collapsed under its own weight.

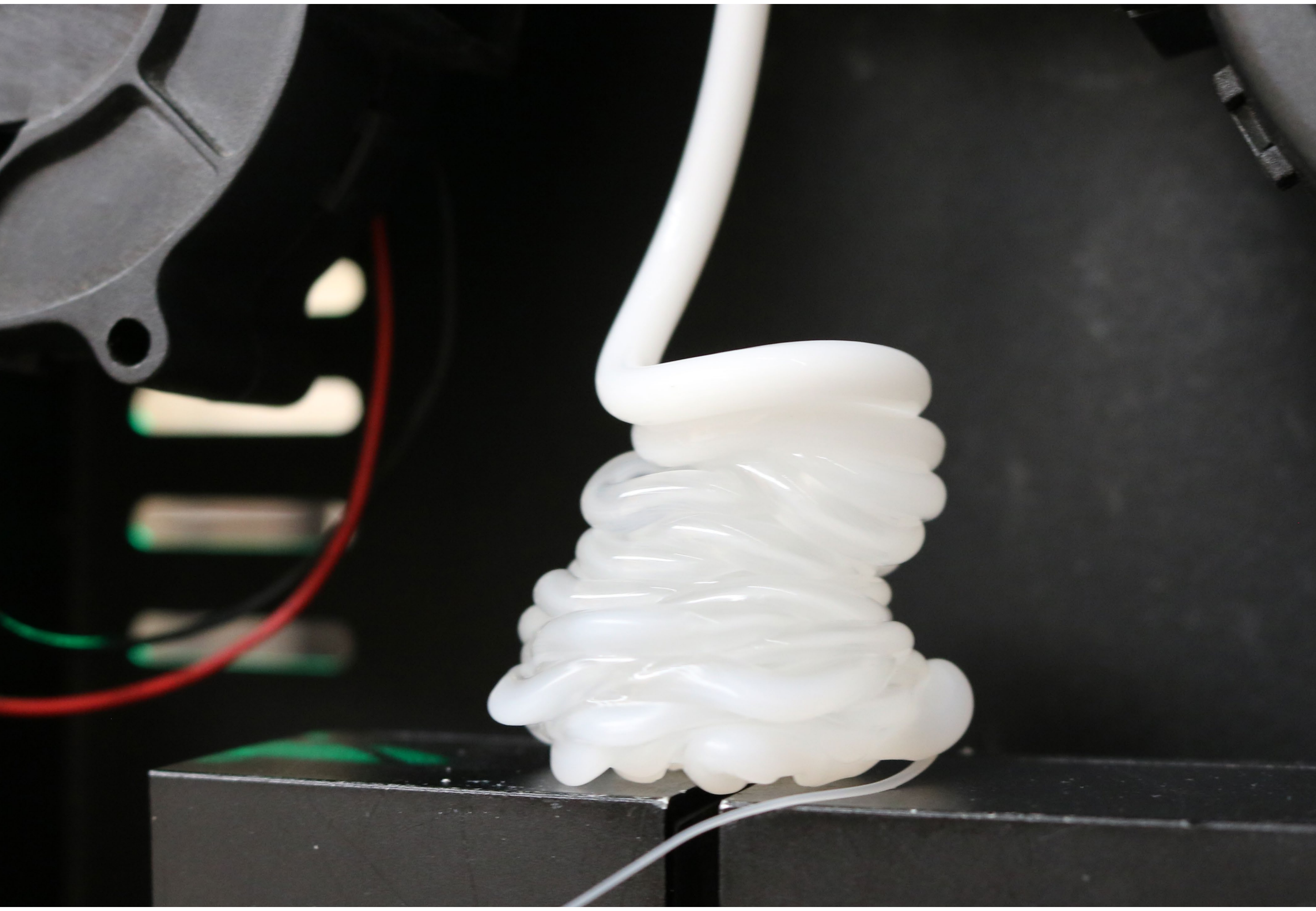

__Figure 4 -__ Transition from purging HDPE (slightly transparent extrudate at the bottom) to ABS (white extrudate at the top)

4. EXTRUSION (2): AJUSTMENT STEPS

The objective was to find the optimal extrusion settings with the help of the filament sensor. Figure 5 is a picture taken during the adjustment phase, before the filament was of sufficient quality to be spooled. The challenge here was to improve output stability, because the flow was surging. This caused a lot of filament diameter fluctuation.

FILAMENT FAN SPEED: Because the extrudate was too solid when reaching the puller, the correct approach was to decrease the fan cooling percentage down to 35%. When the filament becomes solid too soon, it becomes harder for the puller mechanism to adjust the filament thickness.

SCREW RPM: The screw rotation speed was decreased gradually down to 3.5 RPM. This was to give a higher residence time for the material inside the barrel, to ensure more homogeneous melting and more stable flow. Also the output of the material decreases, which makes it easier for the puller mechanism to adjust to the desired thickness consistency.

TEMPERATURES: Since the only problem now was output instability, a temperature profile can be built up. Usually the first adjustments are gradually decreasing all heaters at the same time, because of the fact that the starting point is on the high end of the thermal window, which can lead to signs of degradation (for example foaming or discoloration). Because the output material has the right quality, the temperatures can be adjusted for higher output stability. After experimenting it was found that an ascending temperature profile worked best for this material. This means a low temperature in the feeding section and a high temperature near the end of the extrusion system. This is a common temperature profile in extrusion, especially for amorphous polymers such as ABS.

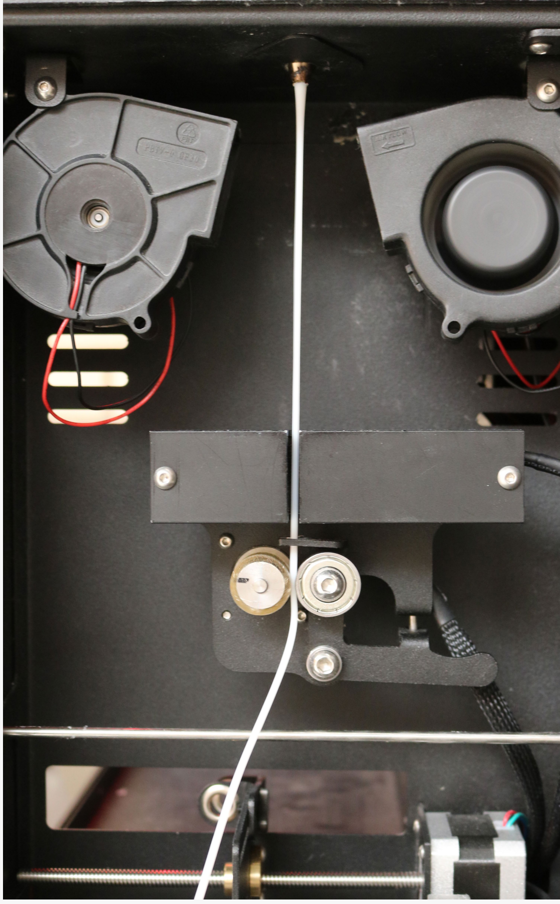

Figure 5 - *Filament flowing freely during the adjustment phase*

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	215 °C	225 °C	235 °C	245 °C	4.3 RPM	50%

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

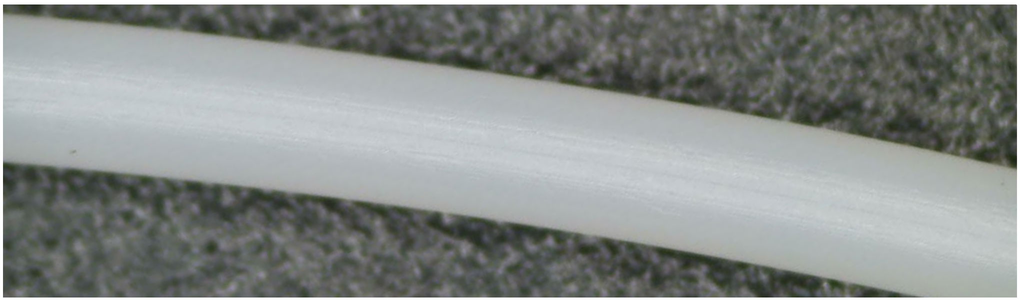

Figure 6 - *Microscope shot to show the visual aspect of the ABS filament : smooth, homogeneous, clear, consistent*

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.

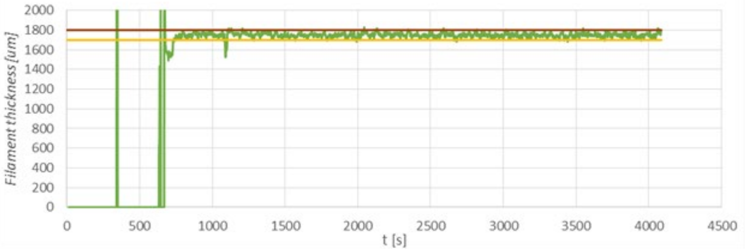

Figure 7 - *Datalog : filament thickness (set value : 1.75mm, red line : 1.80mm, yellow line : 1.70mm)*

Figure 8 *- Spool of ABS*

6. CONCLUSION AND RECOMMENDATIONS

This extrusion experiment was very positive. Indeed, 1.75mm filament of great quality was obtained using a Precision equipped with a 2mm nozzle. Even though the 3D printing of this filament 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 extruded quite easily, without facing any major issue, and that the resulting filament's thickness is easily kept within industry tolerance standards (+/- 50 microns). Figure 8 is a picture of a spool which was obtained at 3devo in a few days of testing. After this test the machine had to be purged clean. This was done fairly quickly with +/- 300 grams of DevoClean Mid-temp purging compound.

REPORT SUMMARY:

TO DOs:

- Dry the material at 80°C for at least 1h in a dryer or an oven.
- Keep high pressure in the extruder. (a 2 mm nozzle helps)
- Purge thoroughly after extrusion using Devoclean MidTemp (at the processing temperatures).
- Transition to HDPE first before processing ABS again. This is not mandatory but will save some time and material.

WARNINGS:

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

Parameter	H4	H3	H2	H1	Screw speed	Fan speed
Set value	215 °C	225 °C	235 °C	245 °C	4.3 RPM	50%