DRYWISE

Markforged Onyx - Drywise Report

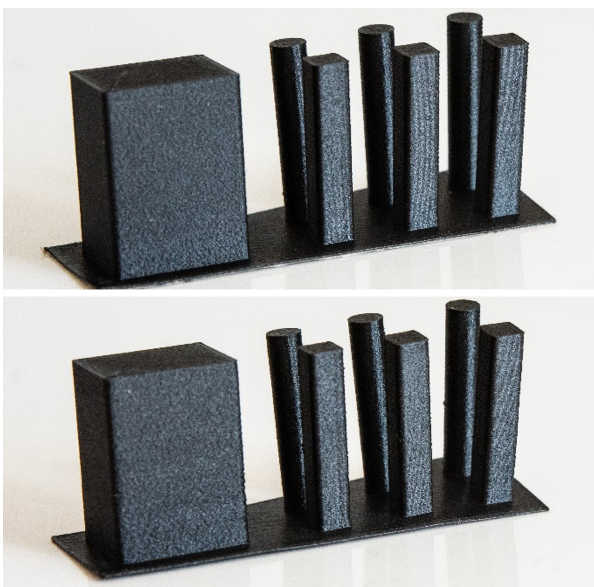
Drywise profile Creation

The Drywise in-line filament dryer takes out the guesswork when 3D printing hygroscopic materials. The Drywise needs a short pre-dry cycle to pre-treat your filament and bring it to the best printing conditions before 3D printing can start. The patent pending in-line design ensures consistently dried material for the best printing results with hygroscopic filaments.

Our team needs to evaluate the filament material to create a tailored filament drying profile for said material type. The Drywise dryer uses an array of smart sensors to treat and monitor the humidity levels in the filament. Once a material drying profile is developed, this material can be added to the Drywise dryer via a firmware update.

Profile Summary – Markforged Onyx

2% samples were used to develop the material profiles discussed here. A PA-CF base profile was used as a starting point for this material. In this case the “Markforged Onyx Pins” was used to benchmark the filament. The resulting prints are compared to the reference print from dry material stored in the pelican case. The settings were modified and the part was printed again until the resulting print was comparable to the reference print. (Figure 1)



Dry filament stored in Pelican case with Desiccant

Filament dried using Drywise (2% Moisture content before processing)

Figure 1: “Markforged Onyx Pins” printed with Markforged Onyx on the Mark Two

A print with wet filament could not be fully printed, in fact several attempts at printing with filament with a moisture content above 2% were unsuccessful since the filament was too soft and caused extruder jams. Nonetheless the partial test prints obtained showed very heavy oozing and stringing, as expected when processing wet material (Figure 2).

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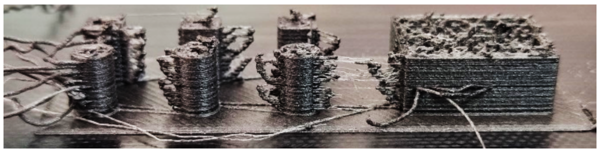

Figure 2: "Markforged Onyx Pins" printed with Markforged Onyx at a hydration level of 2%

When the optimum drying profile was determined, a 10 hour "Printer tolerance print" was printed (Figure 3). Both prints look very similar and show similar tolerance characteristics. None of the prints show any artefacts which are normally attributed to the presence of moisture in the filament. The result of these prints thus confirms that the right profile settings have been identified and also attests to the suitability of Drywise at drying Onyx material.

Dry filament stored in Pelican case with Desiccant

Filament dried using Drywise (2% Moisture content before processing)

Figure 3: "Printer tolerance test" printed with Markforged Onyx on the Mark Two

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Moisture Analysis

Method

Moisture analysis is performed using a RADWAG MA 50-1.R Moisture analyser. About 3.5 m of filament are cut into 2 mm long "pellets", for a total mass of around 10 grams of material. These pellets are then loaded into the moisture analyser for analysis. Gloves are used during the procedure to eliminate the chance of imparting moisture when handling the filament. The moisture was analysed at three different temperatures due to inconclusive results as will be discussed hereunder.

Results

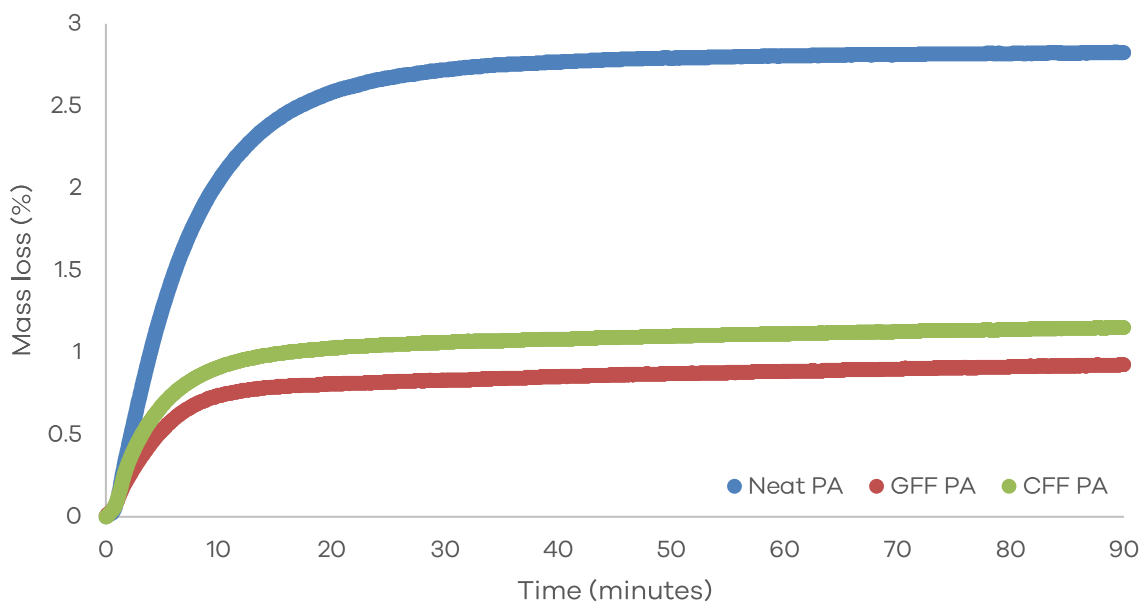

Figure 4: Typical Moisture Analysis curves for nylon materials

Figure 4 above shows results obtained for thermogravimetric analysis of different nylon materials. These results show the typical behaviour of mass loss during a 90 minute moisture analysis cycle at temperatures ranging from 120 – 140 °C, which are the typical temperatures used for analysing the moisture content of plastics. It can be clearly seen that the absolute majority of the mass is lost in the first 10-25 minutes of the analysis, depending on the moisture content of the materials. Materials with higher moisture content typically take longer. Nonetheless after the rapid loss of moisture in the first few minutes the loss of mass slows down significantly and the graph more or less plateaus.

However, looking at the thermogravimetric analysis for the figures below (Figure 5, Figure 6, Figure 7) a different trend is observed. The graphs below are moisture analysis tests conducted on freshly opened Markforged Onyx filament. This filament was stored in a sealed desiccated container prior to analysis to prevent water uptake. The results obtained suggest that the thermogravimetric method employed in this analysis is not suitable for analysing the moisture content in Markforged Onyx filament. As can be seen in the figures below, none of the graphs follow the behaviour of typical nylon filament. Furthermore, even though the moisture analysis at 140 °C and 120 °C suggest that the moisture content is above 2% and the analysis at 100 °C suggest a moisture content of around 1%, yet, the same filament prints with no indication of moisture presence on the Markforged Mark Two.

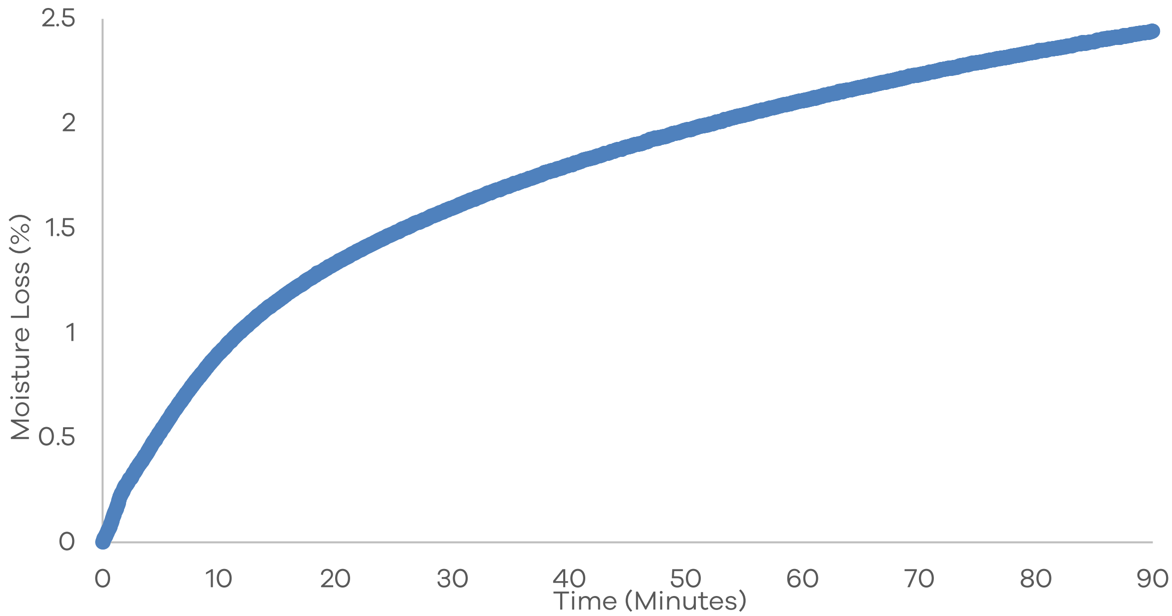

Figure 5: Moisture analysis of freshly opened Markforged Onyx at 140 °C for 90 minutes – 2.44%

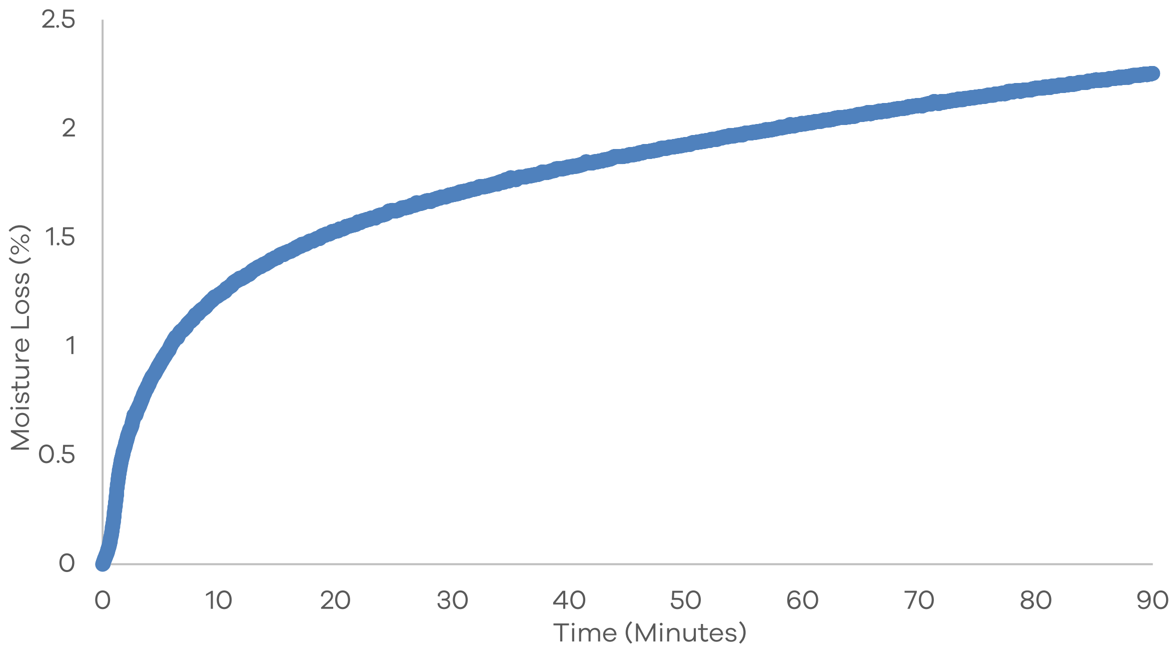

Figure 6: Moisture analysis of freshly opened Markforged Onyx at 120 °C for 90 minutes – 2.25%

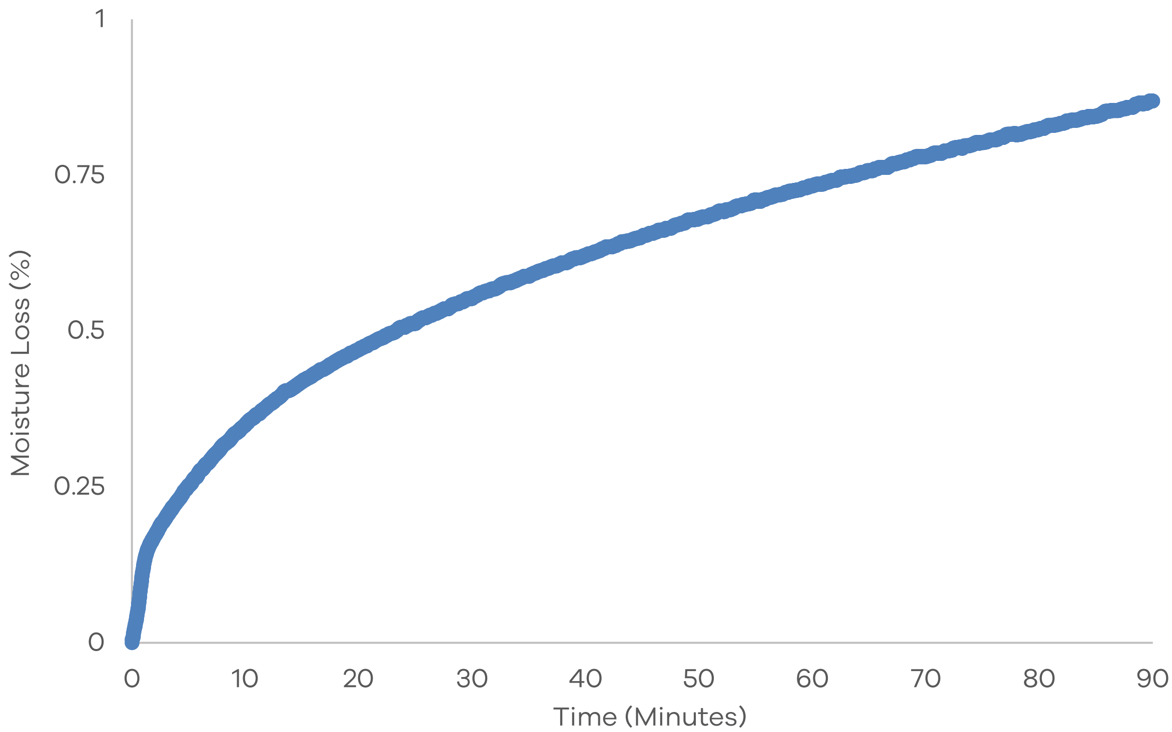

Figure 7: Moisture analysis of freshly opened Markforged Onyx at 100 °C for 90 minutes – 0.87%

As a result, it will be assumed that the freshly opened Markforged Onyx material contains minimum amounts of moisture and all moisture levels quoted in this document will represent the mass in moisture gained by the filament from the freshly opened state.

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Filament Samples

New spool Moisture content

Typically, a Moisture Analysis test is performed on a sample of the material from a freshly opened spool to gauge its moisture level. However, as discussed previously, the moisture analysis tests performed on Markforged Onyx filament did not yield conclusive results. As a result, it will be assumed that the freshly opened filament has minimal levels of moisture and the moisture levels will be defined as mass gained by the filament after opening.

Material hydration

Six samples of 11m lengths were cut from the material and were put in the humidity chamber (set at 75% RH) until they absorbed our predetermined moisture levels. These levels are 2% and 3%, and all the way to saturation, depending on the saturation percentage that the material can reach. These samples will be used for drying testing. The percentage gains in humidity were worked out by weight so each sample was weighed at different intervals with 3 repetitions. An additional 11m sample was left outside in ambient conditions which fluctuated from 50-60% RH and 20-35 °C during the time of testing (Table 1).

The samples stored in the hydration chamber needed some days to reach our target humidity levels. Then, the samples were taken out of the humidity chamber, labelled accordingly and stored in sealed foil bags until used for testing.

Table 1: Material hydration parameters

	75% RH	Ambient
Start hydration	n/a	n/a
Time to gain 2%	2 days	5 days
Time to gain 3%	4 days	n/a
Max Hydration	3.7%	2.5%

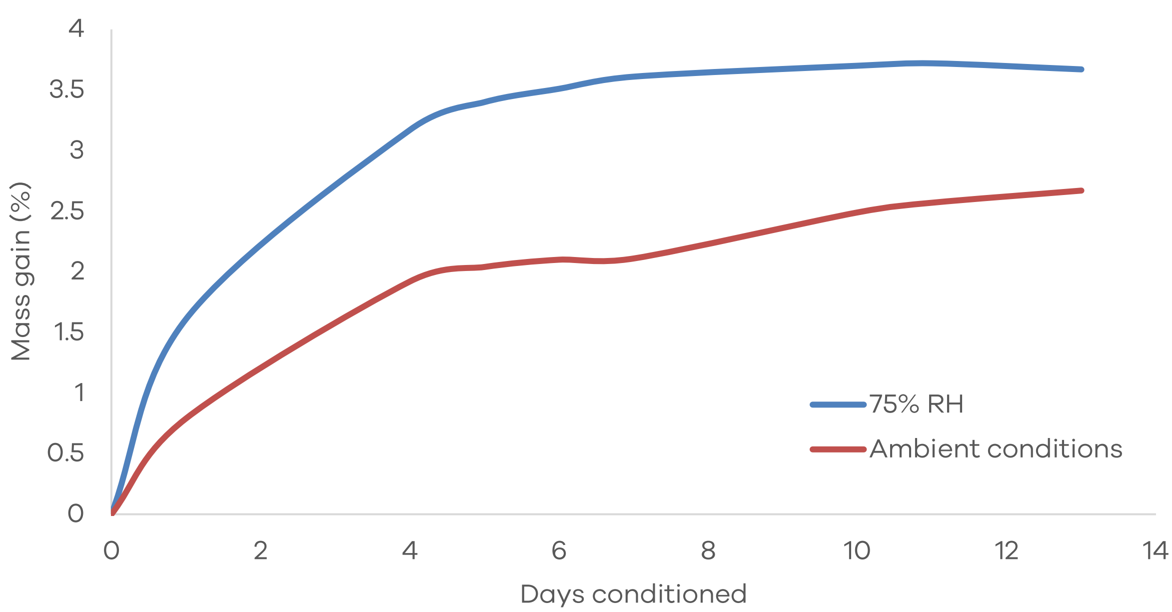

Figure 8: Hydration of Markforged Onyx at 75% RH and at ambient conditions

As can be observed from Figure 8, at 75% RH Markforged Onyx reaches a saturation point when it gains around 3.7% moisture. This level is reached in about a week. On the other hand at ambient conditions Onyx reaches a maximum of around 2.5% moisture gain.

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Printing tests

Each filament profile is developed using two test prints, a short print to test the static drying mode of the dryer and to develop the initial profile settings, and a longer print to test the drying performance during the static and continuous drying modes. For the short print the built-in Markforged Onyx Test Pillars print was used (Figure 9)

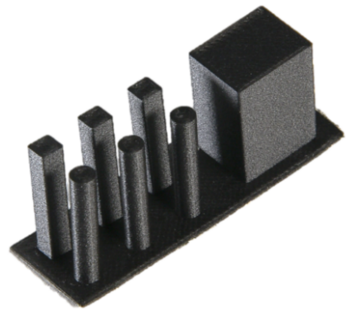

Figure 9: Onyx Test Pillars (source: support.markforged.com)

For the longer print a tolerance test was used (Figure 10). This print takes around 10 hours with the default Eiger settings on the Onyx Two (0.1 mm layer height).

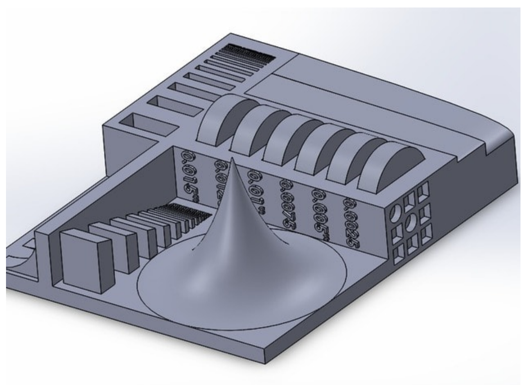

Figure 10: 3D Printer tolerance test (source: https://www.thingiverse.com/thing:636363)

Printing with dry filament samples

These test prints were printed on an Onyx Mark Two using the settings recommended by Markforged unless otherwise stated. The dry filament was stored in a pelican case as soon as it was opened and left inside before and during testing.

Printing with wet samples

The wet (2%) samples were also attempted using the default settings and recommendations from Markforged. However, the attempts proved unsuccessful due to the softness of the filament. This caused the filament to deform and jam the extruder, followed with print failure. Furthermore, at this moisture level, condensation started to form inside the Bowden tube. (Figure 11, Figure 12).

Figure 11: Filament deformation caused by soft wet filament

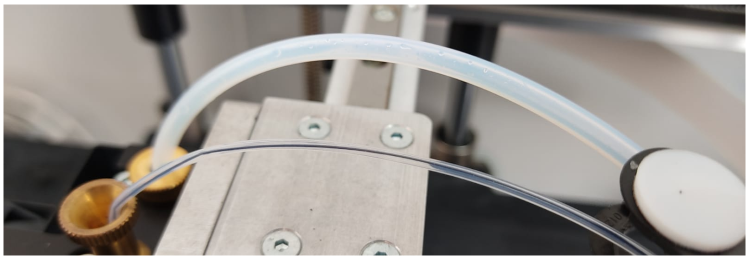
Figure 12: Moisture condensation resulting from wet filament inside the passively heated chamber inside the Onyx Two

Printing with Drywised filament samples and dryer operation

2% hydrated samples were used to calibrate Drywise for use with Markforged Onyx on the Mark Two. To ensure that Drywise works effectively with the Markforged Mark Two, some minor adjustments were needed.

The Drywise unit needs to be placed in such a way to ensure that there is an unrestricted path of filament from the Drywise unit to the printer's extruder. Furthermore, the maximum distance from the Drywise filament output port to the extruder must be of 40 cm. If this is exceeded an additional drying cycle might be required. A PTFE tube of the aforementioned length should be connected between the Drywise filament output to the printer's extruder to ensure that the dried filament is not exposed to moisture and to ensure smooth filament passage.

The current drying profile requires that the filament undergoes a static pre-dry cycle of 30 minutes, after which the filament is loaded into the printer following the user prompts on the Drywise UI. The filament would then require a pre-print cycle of 25 minutes before printing can commence. This ensures that the fresh filament pulled into the machine during loading is also dried before printing commences. The user will be prompted when the print can be commenced.

The Markforged wet plastic purge was disabled as this is not required when using Drywise. The unit will dry the filament, and this can be loaded and used straight away. As a result, using the wet plastic purge will waste filament which has been already dried and will require that the user waits for an additional amount time for the next section of filament to dry before printing can start.

Conclusions

The tests carried out above suggest that Drywise can be used to reliably dry Markforged Onyx filament which has gained 2% moisture. Using Drywise, hydrated filament can be reliably printed on the Markforged Mark Two with little user input and consideration, thus proving to be a promising solution to achieving reliable and consistent results on Markforged printers.

Furthermore, Drywise can function as a Quality Assurance device when used inline going to the Markforged printer. The device will ensure that any prints printed with Onyx filament are at the best material properties.

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