A New Way to Combat the Humidity Absorption of Nylon Materials

Drywise white paper

Introduction

Moisture can play a crucial role in the successful production of FDM (Fused deposition modelling) produced parts. In fact, controlling the moisture in the material before printing enables the user to maximise the potential of the material, produce parts with maximum strength and dimensional accuracy, as well as with the intended surface finish.

This document discusses the importance of using dry filament for FDM prints by assessing the effect of moisture on printed parts, the presence of moisture in new filaments, and the rate of uptake of moisture by filaments with a special focus on Nylon based materials.

Why is Drying Important?

Most thermoplastic materials tend to absorb moisture from the atmosphere, which can affect the printing process. Some engineering-grade materials are especially good at this and can become significantly wet in a matter of days, if not hours. It is also common that newly opened filaments already contain a significant amount of moisture that affects the printing process.

Hissing and popping sounds are the first tell-tale signs that one is printing with wet filament. This happens because the water absorbed by the plastic is very quickly vapourised by the heated nozzle. As a result of this rapid phase change, inconsistent material extrusion and nozzle blockages are common occurrences.

This inconsistent material extrusion will have several visible effects on prints. Stringing and oozing in prints will be more pronounced as the added pressure in the hot end results in less control over the amount of extruded material. The strength of the print will also be negatively affected. As water changes to steam, lots of voids (bubbles) will be trapped inside the filament and ultimately the print, reducing layer adhesion and the overall part strength.

These effects can be observed on several material types such as PET, PEEK, PEI and PC. However, one set of materials which are especially prone to moisture uptake are Nylon or Polyamide (PA) based materials.

The Effect of Humidity on your prints

Neat Nylons

The figure on the right shows the effect of several moisture levels on the printing quality of a neat PA6/66 nylon material (Covestro Addigy® F1030).

At or above 1% moisture content, the print quality of the material suffers significantly with severe oozing and stringing. As expected, the printing artefacts caused by moisture in the material will also affect the dimensional accuracy of the print, especially at higher moisture levels.

Furthermore, a moisture content of around 0.75% is enough to start causing artefacts on printed parts. At this level of moisture the surface finish of the material is inferior to that of parts printed at lower material moisture levels.

Moisture | Neat PA6/66 (Addigy® F1030)

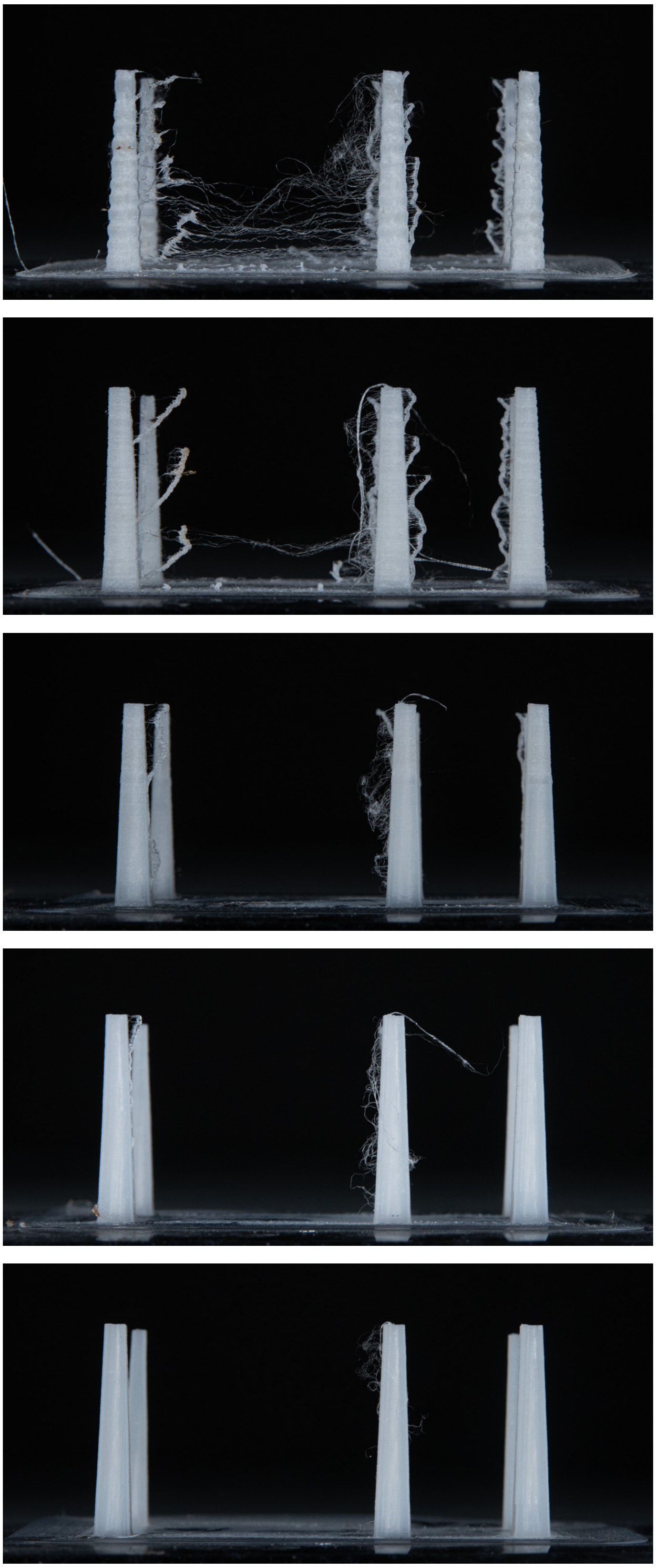
3%

2%

1%

0.75%

0.5%

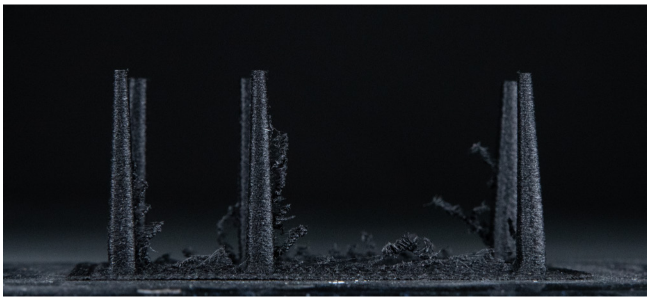


The Effect of Humidity on your prints

Filled Nylons

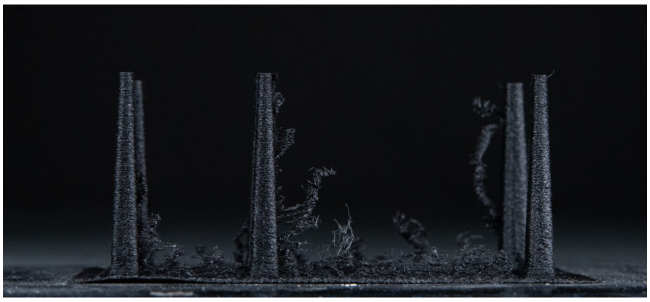
Carbon Filled PA (Luvocom PAHT CF 9891BK)

Moisture



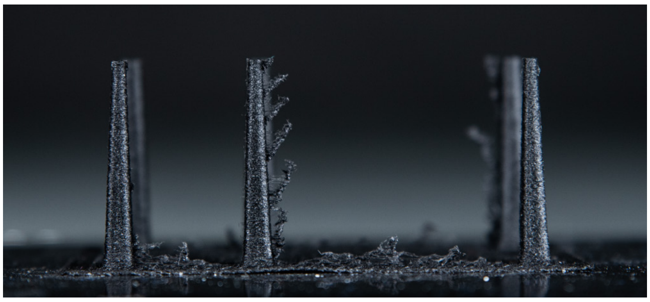
2%

The figure on the left shows the effect of moisture content on a carbon fibre filled filament (Luvocom PAHT CF).

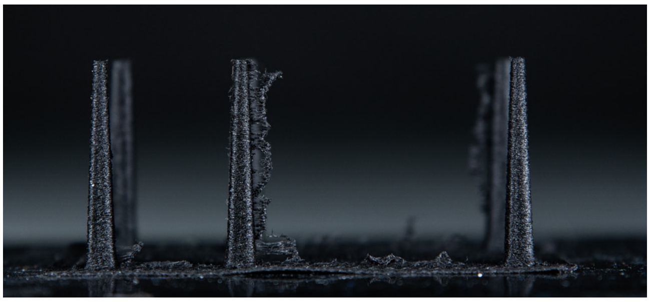


1%

Similar to the previous material, severe printing artefacts can be observed at or above 1% moisture content. However, even at 0.5% and at low moisture levels of around 0.34%, the material still tends to show printing artefacts.

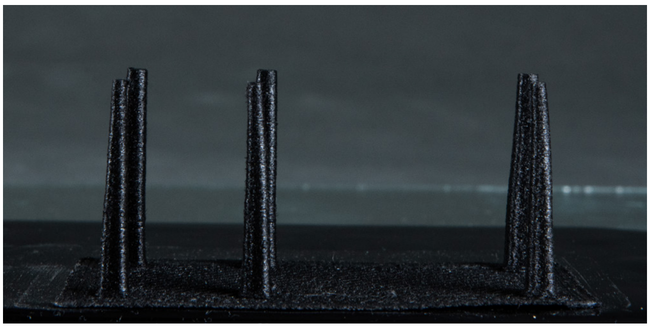


0.5%



0.34%

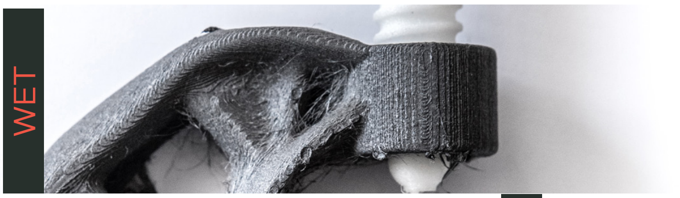
In fact, through several printing tests, it was determined that in general, filled nylon materials tend to start showing printing artefacts at lower moisture levels



Fully dried

Real World Examples

Screw clamp



The clamp on the left was printed with wet Jabil PA0600 (gray) and Covestro Addigy® F1030 (natural) filaments. The filament used for the clamp on the right were Drywised. Apart from the visual imperfections, the clamp which was not dried could not be screwed in due to the variation in tolerances brought about by the presence of moisture in the material during printing.

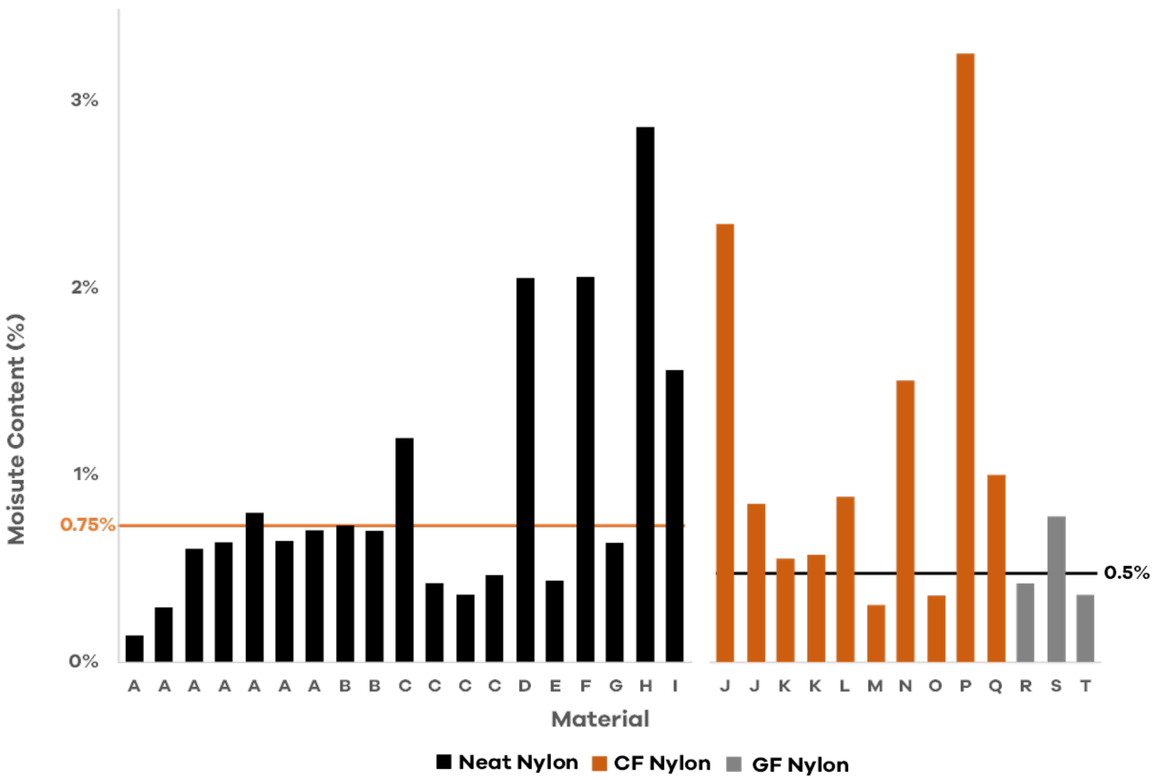
Turbine impellor

The turbine blade on the left was printed with wet Covestro Addigy® F1030 CF10 filament, while the one on the right was printed with Drywised filament. The image clearly shows that all the oozing and stringing has rendered the print unusable. Furthermore, the inconsistent extrusion has caused the thin walls of the part to have inferior strength.

Moisture Content in New Spools of Nylon Filament

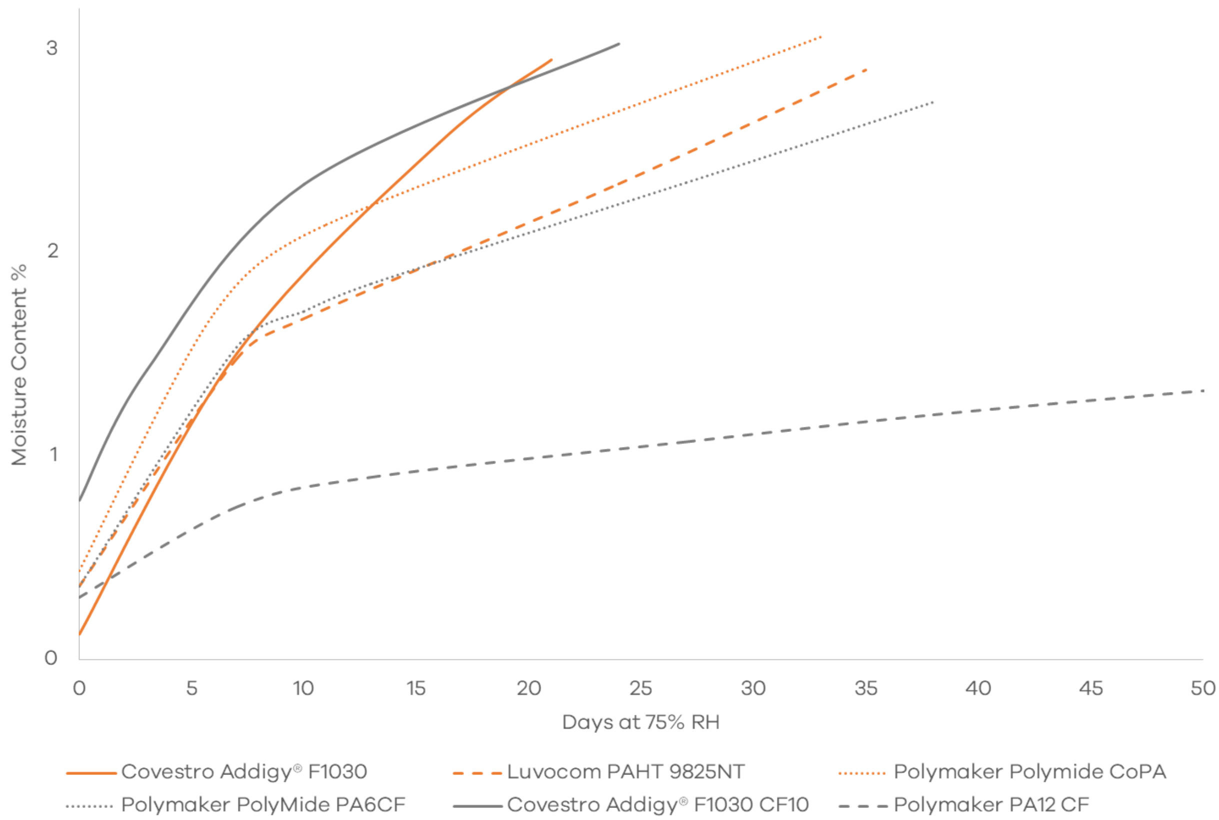
Ideally, a newly opened spool of filament contains as little moisture as possible. In such a case, the user can start printing the material straightaway. The production process of a filament will introduce moisture to the material. Also, while most material manufacturers take precautions when packaging the material, it might still pick up significant amounts of moisture, especially if kept in storage for a long time before being used or if the packaging gets slightly damaged.

Out of 32 randomly chosen materials it was found that most materials have more moisture than the manufacturers recommend for printing. Furthermore, several spools have moisture levels of about 0.75% or more. At this point, nearly all materials will start showing obvious printing artefacts. From our findings, it was also observed that while filled materials tend to absorb moisture more slowly from the atmosphere, these materials also tend to start showing printing artefacts at lower moisture levels of around 0.4-0.6%. The graph below shows that out of 19 neat filaments, 9 of them had moisture contents around or above 0.75%. Furthermore, out of 13 filled filament types, 9 of them had a moisture content of above 0.5%. As discussed previously, at these moisture contents and above, nylon filaments tend to start showing printing artefacts due to the moisture present. The materials have been given a unique code to conceal the manufacturer of the filament.



Moisture Pickup of Nylon Filament

Nylon filaments typically absorb significant amounts of moisture in a few days when left in atmospheric conditions, especially in very humid environments. The figure below shows a number of 2.85 mm nylon filaments treated at 75% humidity at room temperature.

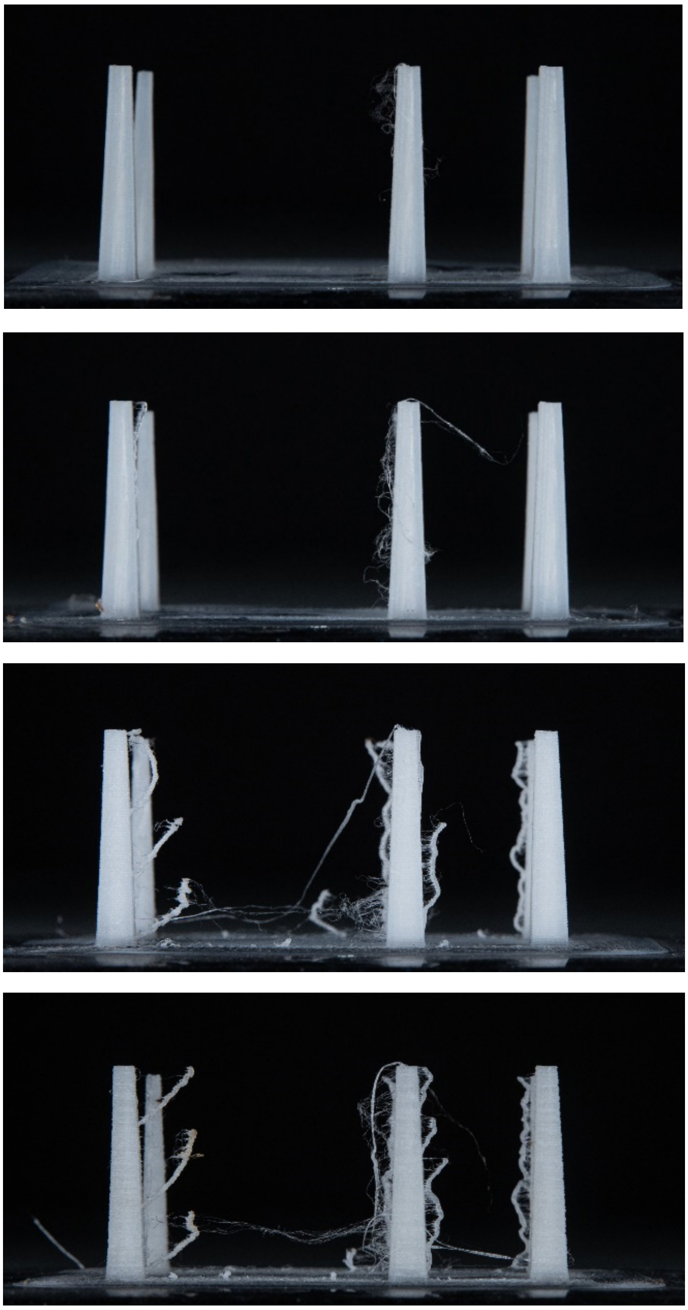


From the graph above, it can be concluded that nylon materials tend to pick up most moisture in the first few days. The rate of moisture then slows down as the amount of moisture increases up to a saturation point. At saturation the filament can no longer absorb moisture. This point will depend on the temperature and humidity the filament is in. This suggests that the material will tend to have significant moisture levels after a few days of use if not dried and stored properly. Furthermore, filled nylons tend to absorb moisture more slowly. However, it was observed that these materials tend to show printing artefacts at lower moisture levels, especially in terms of oozing and stringing. That being said, the moisture uptake of materials tends to be related to the base resin of the material more than the presence of filler materials.

How does this translate to the real world?

Days	Moisture
0	0.65%
1	0.77%
5	1.34%
7	1.60%

Covestro Addigy® F1030

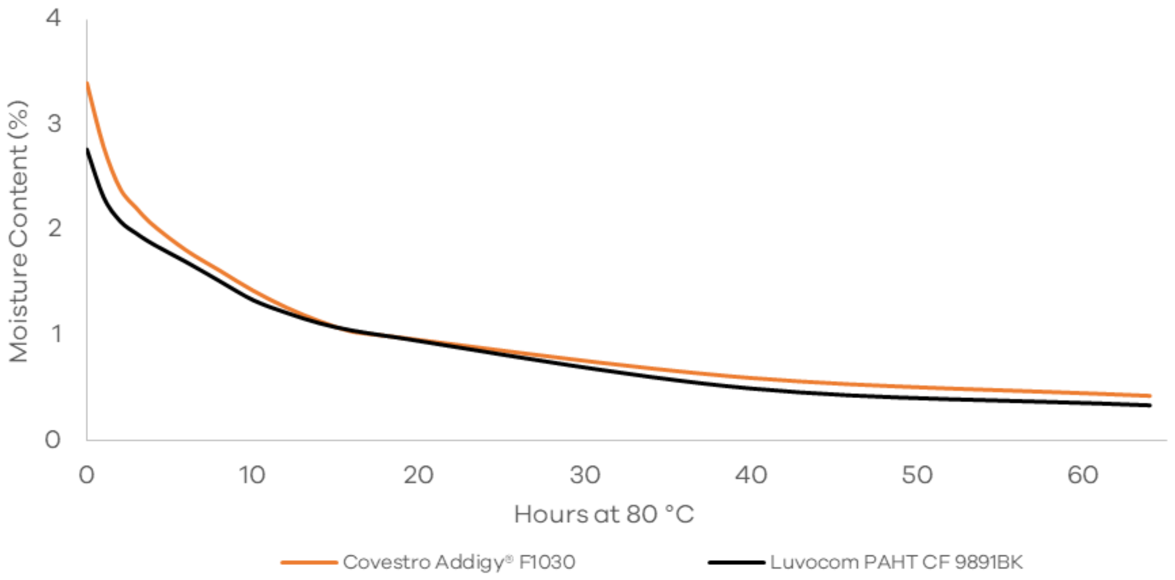


The moisture pickup at 75% RH might not represent the typical conditions for most users. The figure above shows the moisture pickup of a newly opened spool of filament left outside in atmospheric conditions (22 °C, 57% RH). The Covestro Addigy® F1030 started from 0.65% humidity and gained 0.12% moisture in just 1 day. At this level, the filament already starts showing some printing artefacts. After another couple of days, the filament reaches more than 1% humidity. Beyond this point, the filament starts showing severe printing artefacts and the filament would need to be dried before it can be printed.

A New Way to Dry Filament

Filament drying is time consuming

Experienced 3D printing engineers will know that drying filament in an oven usually takes a few days, especially in the case of 2.85 mm filament. As a result, when working with hydrated materials, one will need to wait for a few days before they can reliably print. In most cases, this is not ideal.



From the figure above, it can be observed that it takes at least 40 hours of drying to reduce the moisture content of 3.4% Covestro Addigy® F1030 (2.85 mm) filament to around 0.5%. A level which is acceptable for printing. A further 24 hours are then needed to reduce it to 0.43%. It can also be observed that while the filament loses a lot of moisture initially, the rate of moisture loss slows down as it loses more moisture.

For 2.7% PAHT CF 9891 BK (2.85 mm), the filament requires drying at 80 °C for around 60 hours to reach

0.34%. Again, while the filament loses a lot of moisture in the first few hours, once the filament moisture levels drop to around 1%, the rate of loss of moisture is very slow.

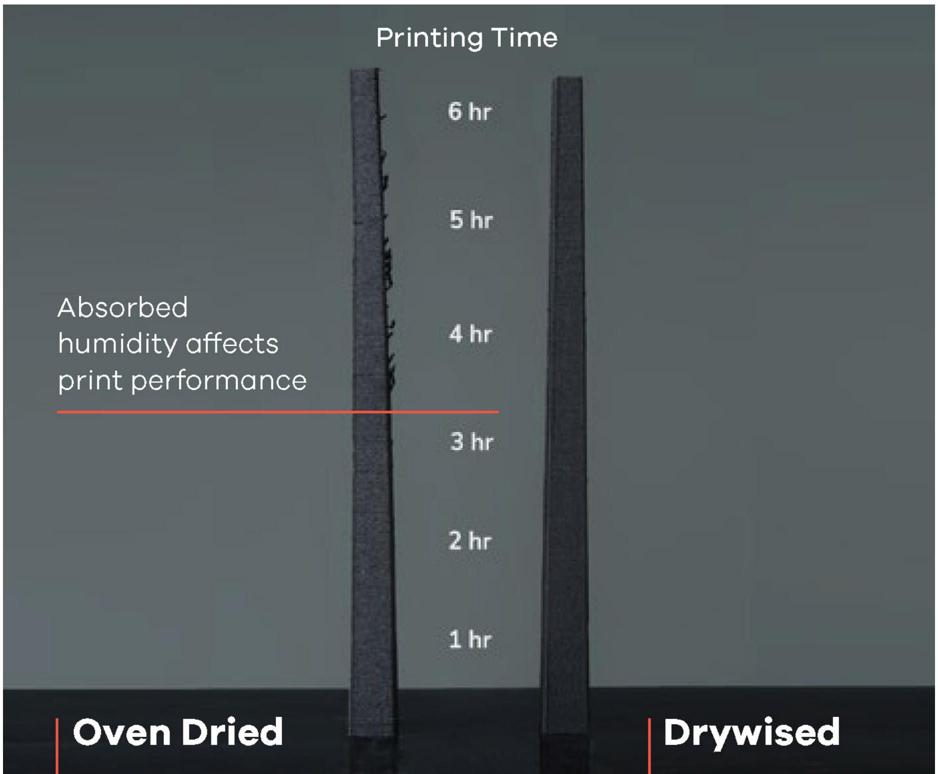
Another drawback of having to dry material in an oven for extended periods of time is excessive energy consumption. This will be compounded by the fact that unless stored properly, the material will absorb moisture again quickly, and would need to be re-dried in a few days. This leads to the next point.

Filament absorbs moisture rapidly

Drying filament is only the first part of being able to reliably print clean and strong parts. As shown above, nylon materials tend to absorb moisture rapidly from their surroundings. The current solution to this problem is either to dry the filament before each use for prints of short duration or to store the filament in a low moisture environment while printing.

There are several solutions on the market for keeping filament dry, such as dry boxes or specialised storage cabinets. However, these units all have their drawbacks. Typically, low-end solutions require constant monitoring and user input to ensure that the desiccant is dry. More advanced solutions are typically bulky and require an active power connection. The biggest drawback of these solutions, however, is that they cannot dry the filament on their own. This means that they have to be used in conjunction with an oven, especially if the filament being used has already absorbed moisture.

Another potential drawback of these solutions is that bigger spools won't always fit in the drying chamber. In addition, some filament spools can warp and degrade in the oven, especially after multiple drying cycles. This can potentially cause the filament to unspool.



Oven-dried filament (60 hr, 80 °C) quickly absorbs humidity from the environment, negatively affecting print performance.

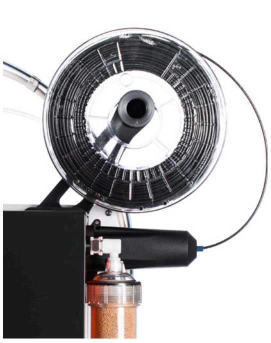
2% Hydrated filament printed using Drywise.

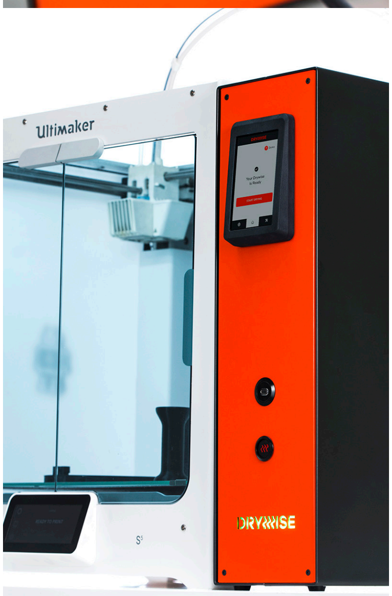
Drywise Solves These Issues.

Drywise aims to address all of these issues since it dries the filament in-line. This means that Drywise only dries the portion of the filament that is to be fed into the printer. The advantage of this is that the printer is always receiving freshly dried filament, ensuring consistent print results. Thus, Drywise addresses both the need of drying filament and also the need of keeping it dry. Furthermore, since the spool is not housed in the unit itself, any spool size can be used with Drywise.

How does Drywise work?

Drywise is an intelligent filament drying unit that sits beside your printer and guides you through the process of drying your filament. The filament can be either placed on the printer, on the Drywise filament spool holder, or anywhere else, given that it has an unobstructed passage to the dryer.





During operation, filament is fed into the Drywise unit via the input port of the machine, where it passes through an internal channel that dries the filament by circulating hot, dry air around it. Dried filament exits the device via an output port that has a filament sensor to detect filament movement. This sensor enables the unit to stop operating should the print finish, or should the filament stop moving unexpectedly. If the filament is appreciably wet, an initial portion of the filament must be pre-treated in the dryer for a period of time, usually between 30 minutes to an hour. This ensures that the first part of the filament loaded into the printer is also correctly dried. If the filament is already dry and the dryer only needs to maintain the filament at the correct dryness, this operation can be skipped..

Once the printer is loaded, the user can start printing and Drywise will do the rest, ensuring that consistently dried filament is fed into the printer during printing. The unit is currently calibrated with most of the Nylon materials available on the market (2.85mm) and new materials are constantly being calibrated and will be available via firmware upgrades.

Find out more about Drywise by vising our website, sending us an email or by booking a short call with us!