Recommendation for processing

Drying of filaments before processing on 3D printer

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Drying is **important for stabilizing every printed object's quality** (without the influence of storage conditions). The material may absorb moisture due to storage out of sachet or after a long time of printing when the spool is in the room, in the presence of long-term used silica gel, but also when stored for a long time in packaging that does not seal perfectly, the material absorbs moisture. Some polymers absorb moisture only on their surface, but hygroscopic materials absorb it into the whole structure. Therefore, the materials were divided into **scales 1–5** (1 – not necessary to dry, 5 – always needed). See column "**The need to dry**" in Table 1.

During the processing of wet hygroscopic materials at melting temperature, water molecules attack individual chains, which are randomly and irreversibly shortened. The reaction takes place at a random point in the polymer chain, thus producing a mixture of chains of different lengths (short, long, half) and this causes processing instabilities, inhomogeneity of structure and final properties. The need to dry the polymer is determined by the structure of the polymer, in particular the type of chemical bonding forming the polymer chain.

The filament must be dried in **the device with exact thermoregulation** (ideally laboratory dryer) – before drying the whole spool, put a little piece of filament into the device for the test of functionality. If the material becomes softer or loses its original shape, lower the drying temperature. In the case of loss of transparency, use a different device.

The spool can't be put into the environment without a controlled value of relative humidity after drying. **The cooling process** must be taken in **the desiccator** (or in the sealing box with the content of silica gel). If the hot spool is placed into an environment with higher humidity, the moisture may be absorbed back in about 10 minutes. And possibly on a higher level of moisture than it was before drying! The coil should not be left in the dryer after it has been switched off, as there is still evaporated moisture in the environment which can be absorbed back into the filament in the same way.

The moisture content in the material influences final properties, the polymer chains are cut and therefore:

- especially **mechanical properties** get worse (= MP), the material becomes more brittle, eventually more flexible,
- **stringing** occurs a lot (fine hair when moving the nozzle),
- temperature and chemical **resistance decrease**,
- **layer adhesion** gets worse, the entirety of the printed object is violated,
- **oozing** occurs (accumulation of material on the side of the nozzle, which may lead to release and contamination of object),
- the **nozzle** can be **clogged** because of the accumulation of degraded material,
- the **under-extrusion** leads to gaps, missing layers, dots, and holes in layers.

It should be noted that the drying temperature is precisely determined by the type of polymer. If a lower temperature is set, the polymer cannot be dried for a longer time with the same result (e.g., Flexfill TPU 98A will not dry effectively at 50˚C for 24 hours). If the temperature is set low, the moisture absorption effect is only promoted as the diffusion rate of liquids increases with increasing temperature. The chains must be slightly relaxed for effective evaporation of water molecules from the polymer. This is achieved above a given temperature, usually the glass transition temperature. However, the extrusion process of the filament affects the temperature resistance of the filament, and so, for example, for PLA at 80 ˚C the filament would be deformed, and the temperature must not exceed 50 ˚C. Therefore, the drying is specified in the table below.

The table is based on the values determined using a moisture analyzer before and after drying in a laboratory dryer. The effect of humidity is described by experimental results when 3D printing wet and dried filaments.

Note: For Flexfill TPU material, we recommend a maximum of 3 drying cycles of 3 hours, after which thermal degradation manifested by yellowing may occur.
For Nylon materials, the drying temperature must not exceed 80 ˚C, otherwise, oxo-degradation of the polymer will occur.
The same level of drying is specified for PLA as for Nylon, because hydrolytic degradation of the chains themselves in the presence of moisture simply occurs. Consequently, it is only the user's view as to whether the manifestations of degradation affect the use of his print.

The material should be stored for a long time in an environment with a humidity of between 5 and 20 %, at a temperature of up to 25 ˚C. Water molecules passively diffuse from the polymer into the silica gel. The higher the concentration of moisture absorbed, the less the ability of the filament to keep dry. Therefore, after a certain period of time, the silica gel needs to be re-dried under the conditions shown in Table 1.

Fillamentum is not responsible for the moisture content of the filament, nor is Fillamentum liable for material failure due to improper printing or failure to comply with recommended processing conditions. The company is not responsible for irreversible damage to the filament if improper drying, cooling, or storage equipment is used.

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Table 1: Recommended conditions for drying of Fillamentum products.

MATERIAL	MINIMUM TIME OF DRYING	TEMPERATURE OF DRYING	THE NEED TO DRY	THE CONTENT OF MOISTURE CAUSES:
ABS EXTRAFILL	2 h	80 °C	2	process instability
ASA EXTRAFILL	2 h	80 °C	3	process instability, low layer adhesion (colour Metallic Grey)
CPE CF112 CARBON	5 h	75 °C	5	stringing, MP, oozing
CPE HG100	5 h	75 °C	5	stringing, MP, decrease of temperature and chemical resistance, bubbles, "foamy" appearance of printed object
FLEXFILL PEBA 90A	5 h	70 °C	5	stringing, MP, bubbles, low layer adhesion, low bed adhesion, surface quality
FLEXFILL TPE 90A	2 h	80 °C	2	/
FLEXFILL TPE 96A	2 h	80 °C	2	/
FLEXFILL TPU 92A	3 h	80 °C	5	stringing, under-extrusion, clogged nozzle
FLEXFILL TPU 98A	3 h	100 °C	5	stringing, under-extrusion, clogged nozzle
FLUORODUR	2 h	80 °C	1	/
HIPS EXTRAFILL	3 h	70 °C	1	/
NONOILEN®	2 h	70 °C	2	stringing, MP
NYLON AF80 ARAMID	4 h	80 °C	5	MP, colour change
NYLON CF15 CARBON	4 h	80 °C	5	stringing, MP
NYLON FX256	3 h	80 °C	5	stringing, MP, bubbles
OBC 905	2 h	80 °C	1	/
ORCA®	>5 h	80 °C	5	stringing, MP, decrease of temperature and chemical resistance
PC/ABS	4 h	80 °C	5	stringing, MP, surface quality
PETG	4 h	65 °C	5	stringing, MP, bubbles, sputtering, "foamy" appearance, under-extrusion
PETG HFFR	4 h	65 °C	5	stringing, MP, under-extrusion
PLA CRYSTAL CLEAR	4 h	50 °C	5	stringing, MP, clogged nozzle, optical clarity
PLA EXTRAFILL	3 h	50 °C	5	stringing, MP
PORTHCURNO	>5 h	80 °C	5	stringing, MP, decrease of temperature and chemical resistance, bubbles
PP 2320	2 h	80 °C	1	/
SILIKAGEL	24 h	120 °C	5	reduced efficiency for filament moisture stabilization
TIMBERFILL®	2 h	50 °C	5	stringing, MP
VINYL 303	2 h	70 °C	1	/

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