Arnitel® ID

Overcoming 3D printing speed limitations of flexible soft plastics with Arnitel® ID

As the 3D printing market continues to grow and increase in sophistication, more materials are becoming available to enable users to convert their computer files directly into solid reality. One of the most recent entries into the field is Arnitel® ID from DSM, a high performance, flexible thermoplastic copolyester elastomer (TPC) filament with a renewable content of over 50%. The first member of this new family has a Shore D hardness of 35.

Among the various advantages of Arnitel ID is that its better thermal stability (125°C) enables printed parts to be used in conditions where standard PLA (Polylactic Acid) would not be suitable. Plus, of course, Arnitel ID is much more flexible than PLA – and it is the world's first flexible bio-based thermoplastic.

Arnitel ID filament can be used with any fused filament fabrication 3D printer that supports commonly used PLA filaments, since required extruder temperatures for the two polymers are very similar. But as with any flexible material for 3D printing, certain specific processing aspects need to be addressed.

3D printing issues

Various issues relating to feeding arise when 3D printing with flexible filaments. Processors need to consider such aspects as:

- unwinding from a reel
- buckling of filament
- grinding by transporting wheels
- temperature homogeneity
- high crystallinity (ΔH) polymers
- high melting point (T_m) polymers.

When 3D printing with filaments of soft and flexible plastics, a problem that commonly arises is that the filament may buckle and even be damaged by the transport wheels. As a result, the filament becomes stuck in the printer and the printing process is interrupted. We will concentrate here on the issue of buckling as it applies to highly crystalline, high melting point polymers like Arnitel ID, and the work that DSM has done to resolve them.

Fused Filament Fabrication (FFF) printers—often referred to as FDM printers (FDM stands for Fused Deposition Modeling, a Stratasys technology)—generally use one of two types of filament feeding systems, known as Direct and Bowden. In both cases, the filament passes directly into the hot end after passing between a driven gear—which effectively grabs it—and a smooth surfaced wheel. With printers using the more recently introduced Bowden approach, the filament passes through a flexible tube that separates the extruder from the hot end; this enables the extruder to be mounted in a fixed position while the hot end moves as it lays down the filament to create the part.

In both cases though, there is potential for the filament to buckle immediately after it exits the drive wheels, due to the free space between the wheels and the hot end or the delivery tube (see diagram). For printers with Bowden type extruders, constrained buckling may also occur in the flexible guiding tube.

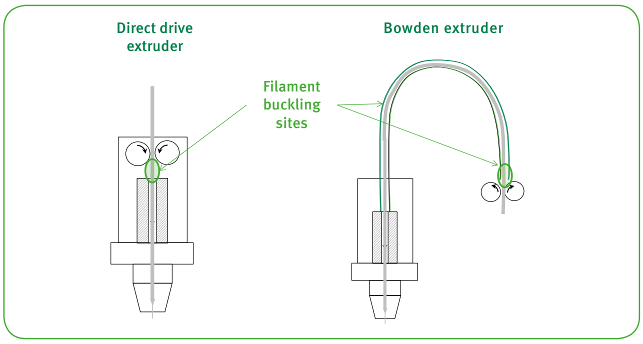

Fig. 1: filament feeding systems

The force driving the filament largely determines whether or not buckling actually occurs. But in any case, the phenomenon is more likely to occur with flexible polymers, such as thermoplastic polyurethane (TPU) and thermoplastic copolyester elastomer (TPC). The phenomenon can be equated to trying to move a rope by pushing it on one end.

To overcome buckling problems, two different aspects of the process need to be considered in particular:

1. the design of the feeding system, especially the length of the free space after the drive;
2. the feeding force put on the filament, which is largely determined by:
    - the pressure required to push the melt through the nozzle;
    - the friction of the filament in the guiding tube (with the Bowden drive).

With any given printer, various measures can be taken to lower the feeding force to prevent flexible materials from buckling. For example, the melt pressure in the nozzle can be reduced by changing the printing conditions:

- reducing the flow rate (that is, the printing speed);
- raising the filament temperature;
- or even choosing a larger diameter nozzle.

Reducing the viscosity of the material will also have a similar effect, but this will seriously affect other aspects of printability.

In most cases, a balance has to be found between the printing speed and consistency of feeding. This will generally result in a speed that is lower than can be used with more rigid materials. Researchers at DSM have been analyzing the balance between buckling and printing speed, and developing ways to predict it in practice. The buckling of a cylindrical rod under a load is determined by the length (L_B) and diameter (d_f) of the rod, the modulus (E) of the material, and the applied load ($P_{buckling}$). For demonstration purposes, we can assume that the load is directly proportional to the melt pressure in the nozzle (pressure=load/surface area).

The minimum length for such a rod to buckle—the critical buckling length—can be estimated using the following equation:

$$L_B = \frac{\pi d_f}{4}\sqrt{\frac{E}{P_{Buckling}}}$$

The graph below shows how the critical buckling length of two flexible materials with two different softnesses (Shore D values) and two different filament widths (1.75 and 2.85 mm) varies according to the printing speed when printing a 0.2 mm thick layer using a 0.4 mm diameter nozzle (giving an “extrusion width” of 0.5 mm). For commonly used printing speeds in the range of 50 – 100 mm/s, the critical buckling length is estimated to be less than 6 mm. As can be seen, printing with a thicker diameter gives also less buckling. Lowering the speed is effective for a better feeding.

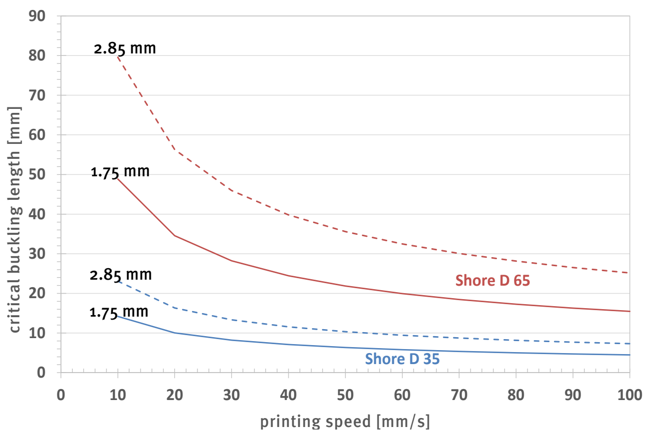

Table 1: critical buckling length [mm]

Lowering the surface friction of the filament—which for flexible materials is generally higher than for common rigid materials used in 3D printing such as PLA and ABS—will facilitate unwinding the filament from the reel and also reduce the feeding load. Surface friction can be reduced by incorporating surface-active additives (also known as release agents) into the material, but they do have an important drawback: they reduce inter-layer adhesion in the 3D part.

DSM has built up many years of experience in developing materials for cable and wire applications, where surface friction is an important phenomenon. The company has been able to use this experience in the development of Arnitel® ID, which incorporates technology that provides significantly lower friction than other commercial soft filaments, without affecting adhesion. Companies using Arnitel ID in their FFF 3D printers can therefore optimize their printing speeds while keeping very good layer-to-layer integrity. It is possible to achieve speeds of up to 60 mm/s, which is more than twice as fast as what is normally possible with TPU (top speed is around 25 mm/s).

Conclusion

Although filament buckling of flexible thermoplastics in 3D printers can be avoided by lowering the viscosity of the material, this is not a viable option in practice, since it has too large an impact on the printability and part performance. For this reason, DSM has concentrated on an alternative approach.

Arnitel ID filaments have a surface that is lubricated in order to reduce surface friction while keeping interlayer adhesion in the printed part at a high level. In this way, the influence on the printer in terms of critical buckling length is minimized, and a higher printing speed can be achieved. For example, when processing Arnitel ID on an Ultimaker 2+ with Bowden set-up, it is possible to achieve printing speeds of 50-60 mm/s and still produce high quality parts.

Technical features

Density iso 1183: **1100** kg/m³	Operation temperature: **125°C 257°F**
Elongation at break: up to **390%**	Water absorption: **0.04%**
Shore: **D 34**	UV resistance: **Good**
Print speed mm/s: **20-50**	Extrusion temperature: **230°C 446°F**

Contact us

If you would like to know more about our Arnitel ID contact us to today.

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