DRAFT V.2.3

Leapfrog 3D Printers
Filament Guide 2019

E-PLA
Engineering Polylactic Acid

ABS
Acrylonitrile Butadiene Styrene

PETG
Polyethylene Terephthalate

NYLON
Nylon

PP
Polypropylene

CARBON
Carbon Composite

HIPS
High Impact Polystyrene

PVA
SCAFFOLD

FLEX
Thermoplastic Polyurethane

Leapfrog™
3D Printers

Leapfrog 3D Printers

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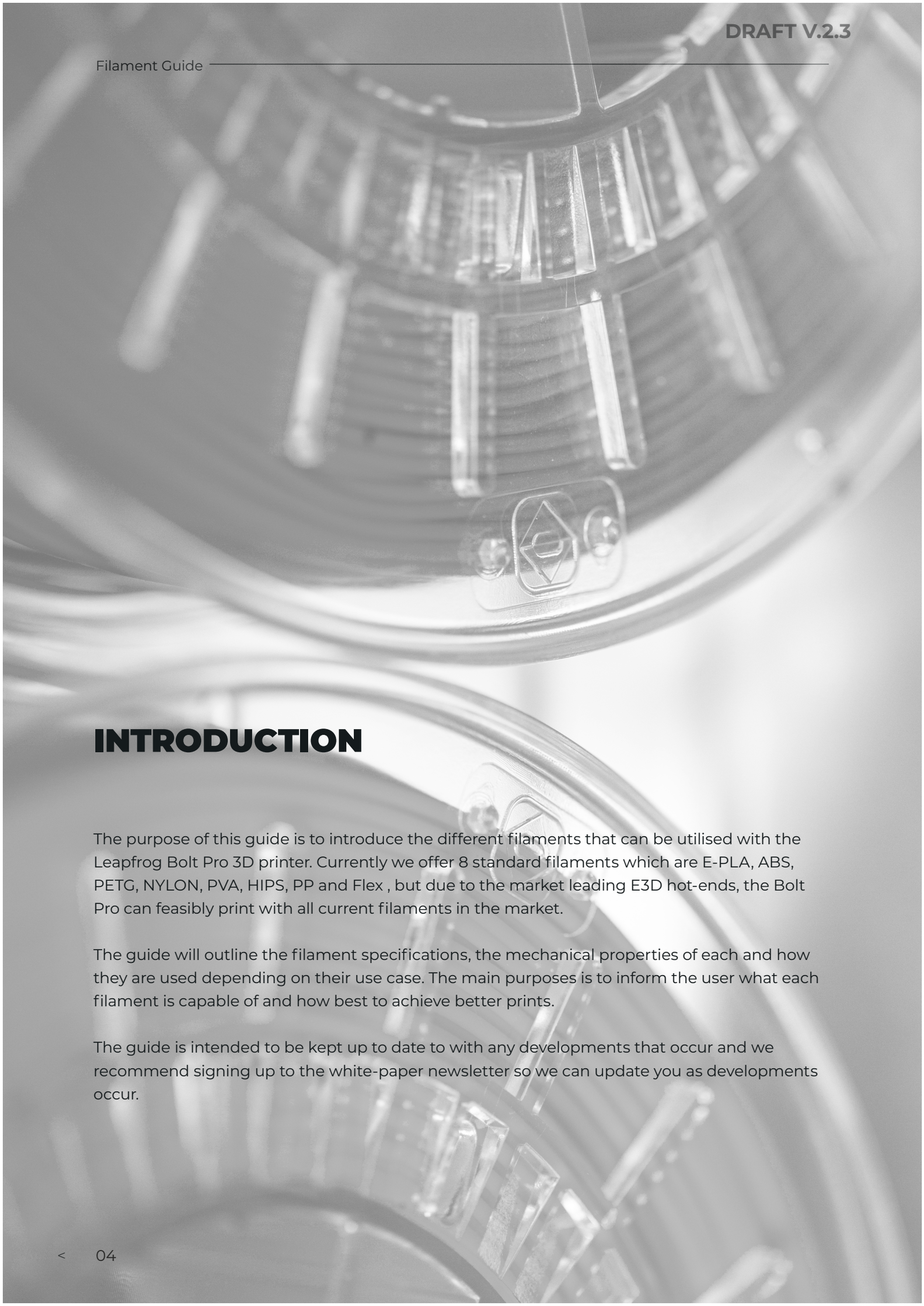


INTRODUCTION

The purpose of this guide is to introduce the different filaments that can be utilised with the Leapfrog Bolt Pro 3D printer. Currently we offer 8 standard filaments which are E-PLA, ABS, PETG, NYLON, PVA, HIPS, PP and Flex , but due to the market leading E3D hot-ends, the Bolt Pro can feasibly print with all current filaments in the market.

The guide will outline the filament specifications, the mechanical properties of each and how they are used depending on their use case. The main purposes is to inform the user what each filament is capable of and how best to achieve better prints.

The guide is intended to be kept up to date to with any developments that occur and we recommend signing up to the white-paper newsletter so we can update you as developments occur.

GLOSSARY OF KEY TERMS

LAYER HEIGHT

Layer height plays a few roles in the context of 3d printing. Layer height is the height of each layer that is extruded by the printer. Higher layer heights are quicker to print, but at the cost of strength and aesthetics of the print model.
One thing to note is layer height is not the same as resolution. Resolution determines the level of detail of an object. However, layer height does affect resolution. Layer height is also determined by the size of the nozzle you are using therefore that needs to be taken into consideration.

PRINT SPEED

When we talk about printing speed, we are speaking about a few separate settings that affect the quality, lead time and different aspects of the printing process. These settings are not universal and are dependent on the complexity or requirements of each model and the material that is used. These speed settings can be adjusted in the G-code to enhance the results of certain objects.

1. Print Speed: This is the speed at which the extruder travels when printing

2. Travel Speed: This refers to the speed at which the extruder can travel when moving to the next position during a print job when it is not extruding any material.

3. Extrusion Speed: (Extrusion Multiplier): The extrusion speed, or flow rate is the amount of filament laid calculated as mm^3/s).

4. **First Layer Speed:** First layer speed determines the print speed of the bottom layer. This can be reduced to improve bed adhesion for certain filaments.

5. **Infill Speed:** Infill is the amount of internal material used that determines how hollow or solid an object is. The infill print speed therefore can be reduced to reduce print time since this area is not visible.

6. **Outer/Inner Shell Speed:** A 3D printed object often has a shell that makes up the exterior of the model. This exteriors print speed can be adjusted to improve the visual quality of the object.

BED ADHESION

The bed adhesion process is important during the printing process for a number of key reasons. It is crucial for the first layer of an object to adhere well to the print bed because it can lead to warping or the object being separated from the print surface leading to a failed print. Although we provide a BuildTak sticker for this, not all filaments adhere well to it and will require alternative adhesive stickers which will be mentioned later.

ENCLOSURE

There are two modes of printing. Printing with the printer enclosed protects against VOC that some filament can produce, like ABS with the added benefit of offering better stable ambient temperature effects during the printing process. This is especially important for the more hard to print filaments that may warp during the printing process.

STL

Stereo-lithography file format is the most common 3D printing file format and most CAD software can export models in this format.

SLICING AND SLICER SOFTWARE
Slicer software takes an STL file and slices it into layers that are printable. All required settings for the printing material such as extrusion temperature, layer height and speed can be adjusted in it. After all the adjustments are made, you can use Slicer software to export a G-Code that is a set of instructions that the Bolt Pro or Xcel 3D Printer can follow to print the desired object.

INFILL
Infill percentage defines how dense the print model is. Low infill percentages reduce material use and make the object lighter, while more infill makes it more sold. This also has an impact on how quick the model is printed.

OVERHANG AND BRIDGES
An overhand is the angle that is possible to printed without having support material holding up the model. It is how far an object extends from the base structure. For 3D printing, an angle over 45 usually requires support material.

A bridge in the context of 3D printing refers to 3D printing material between two points that hang in the air with a gap below.

POST PROCESSING
Post processing is the steps that can be taken or required after printing the object. It includes sanding, support removal or painting. Each material has different possible post processing process that can be used depending on its properties.

SUPPORT
Support is either using the same material or another that is used to help to hold up the structure of an object. The most common materials are PVA and HIPS. However, it is also possible to create support material using the same material using a second extruder that can be removed with some pliers. This is often called break-away support.

WARPING
Warping occurs due to material shrinkage as the object cools. This affect can create deformities as some parts cool faster than others and pull the object off the print bed. It is most pronounced at the edges of an object.

CRACKING
Cracking is similar to warping but occurs in later stages of the printing process and usually has different causes depending on the material.

SKIRT
A skirt is a printed outline that surrounds your 3D printed part that does not touch the printed object. It is printed first before the part and is used to prime the extruder before it starts printing the part. This helps determine smooth flow of the material and helps you to detect incorrect settings such as bed levelling or insufficient bed adhesion before continuing the print job.

BRIM
A brim is similar to a skirt with differences being it being attached to the edge of a print object and that it extends outwards but only being a few layers thick. Its purpose is to help with bed adhesion and to reduce warping of objects, especially parts that have a narrow base which has less surface area touching the bed.

FILAMENT PRESSURE THUMBSCREW

In order to support a wide variety of filaments the extruder of the Bolt PRO has been designed in such a way that the pressure can be adjusted on the extruder motor. For each material a recommendation on tension will be given

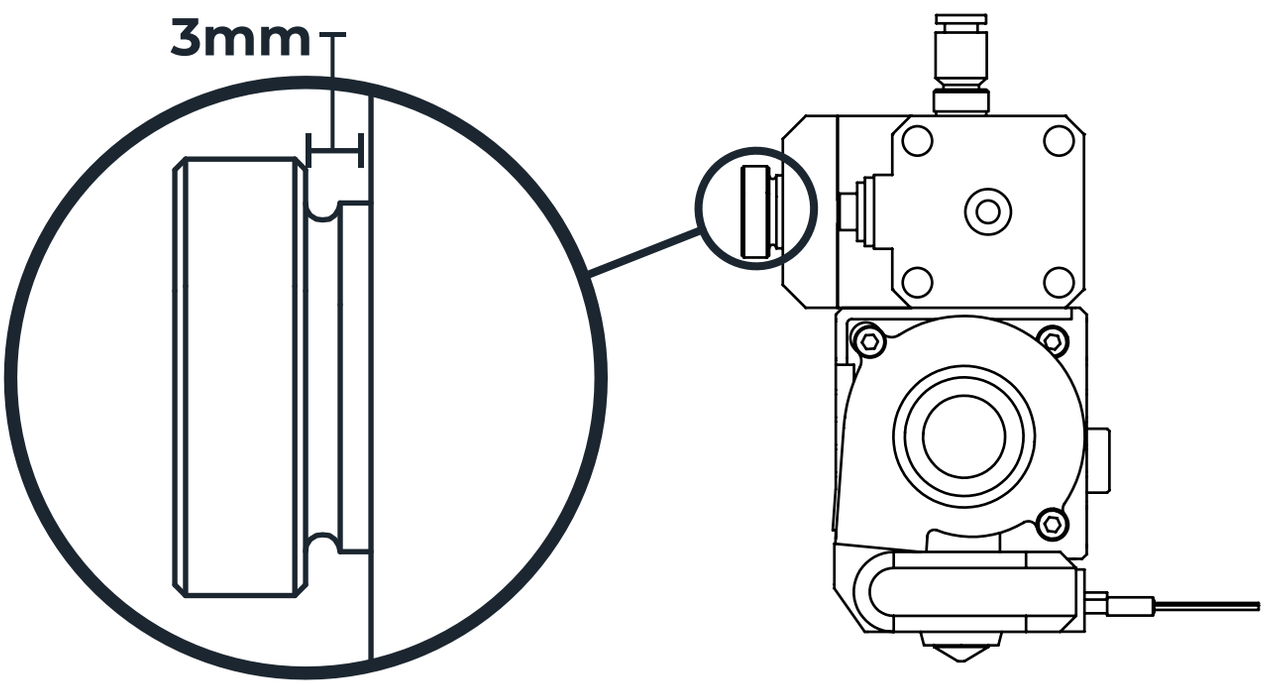


Diagram: Thumbnail screw on extruder

MATERIAL COMBINATION MATRIX

The great advantage of the Bolt Pro 3D printer is it comes with dual independent extruders (IDEX). This means that users have the option of combining two materials to use one as a support or to use different colours of the same material to create unique models.

However, each 3D printing material has unique material properties and these become increasingly important when attempting to combine two different types of filaments.

The matrix below highlights which combinations work well with each, which materials that can be used as breakaway support and which material combinations that will not work when combined.

	DISTINGUISHING FEATURE
EPLA	**Aesthetics** : E-PLA can create great visual prototypes with the added option of post processing such as painting or being able to be sanded to create great models. **Ease of use**: E-PLA is the easiest material to work with that does not have unique work-flow requirements.
ABS	Heat resistant : Wear resistant: ABS models do not scratch easily and can last long if stored properly.
FLEX	High Elasticity: Very flexible and can stretch.
PETG	UV Resistant: Many models degrade if left out in direct sunlight, PETG is the main exception in 3D printing. Water Resistant: PETG models can be used to store liquids or be submerged without degrading.
PP	Chemical Resistant: PP is highly resistant to chemicals and cannot be combined to anything apart from itself. Fatigue Resistant: PP models do not break easy from repeated flexural forces.
Carbon	High Strength: Carbon is added to a base filament to increase strength and rigidity in the final model.
Nylon	Low Friction: Great for models that require movement without degrading.
HIPS	Soluble material: HIPS dissolves in citric based acids. Impact Resistant: HIPS is highlight impact resistant and can withstand forces for various functional applications.
PVA	Soluble Support Material: PVA dissolves in water and is used for complex geometric models.

	EPLA	ABS	FLEX	PETG	HYBRID	PP	Carbon	Nylon	HIPS	PVA	Breakaway
EPLA	●	○	○	○	○	○	○	○	○	▥	▥
ABS		●	○	○	○	○	○	○	▥	○	▥
FLEX			◑	○	○	○	○	○	○	▥	○
PETG				●	○	○	◑	○	○	○	▥
HYBRID					●	○	○	○	○	○	◑
PP						◑	○	○	○	○	◑
Carbon							●	○	○	○	▥
Nylon								◑	○	◑	▥
HIPS		●							●	○	▥

Verified for most applications	●
Limited applications	◑
Not viable	○
Used as support material	▥
Limited use as support breakaway	◑

* Breakaway support means using the same material as a support material that can be removed with careful cutting after printing.

Table 1: Material combination matrix

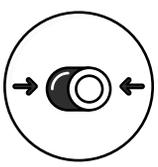
ENGINEERING POLY-LACTIC ACID (E-PLA)

E-PLA is a version of PLA formulated to have higher mechanical properties like strength than standard PLA.

It is catered to the high demands of the current 3d printing industries that need a filament that is both easy to use, sticks well to the print bed and still has the ability to print high-quality prints with out to much hassle.

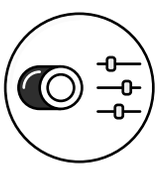
We highly recommend E-PLA for new 3D printing users due to its high predictability when in use.

WHY USE IT



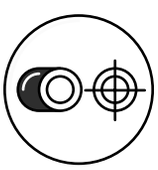
Strength.

E-PLA strength is greater than the standard PLA and has great impact resistance for many use cases. Users can create great models and use E-PLA to create tooling easily for their enterprise.



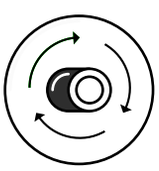
Ease.

E-PLA has a low melting temperature and can benefit aesthetically from active cooling. This makes it a great filament to start with since it isn't prone to warping like ABS



Accuracy.

E-PLA is not prone to warping or cracking like other filaments, therefore tolerances are easier to achieve in comparison to other filaments.



Biodegradable.

E-PLA is derived from natural sources such as sugar-cane or corn. This makes it biodegradable and will degrade within 6-12 months if it is discarded.

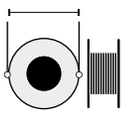
Disadvantage

E-PLA has some degradation issues where the colour fades as time passes, especially if it is exposed to direct sunlight.

Disadvantages

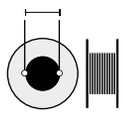
E-PLA does not have much heat resistant properties where the it begins to soften at 60 °C.

E-PLA



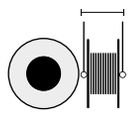
Outer Diameter

200 mm



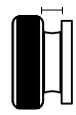
Centre Hole Diameter

52 mm



Width

54 mm



Thumbscrew Tension

3 mm

FILAMENT INFORMATION

Filament Diameter

1.75 mm(± 2%)

Filament Weight

750 g

Filament Length

168 mm

Specific Gravity

1.25 g/cm³

Available Colours

PRINTING & STORAGE

Extrusion Temperature

±210 °C

Temperature management is key with any print object. If the temperature is too high then the printing process will include a lot of oozing and mess. If instead, prints are not adhering to the bed and you are getting blobs, then the temperature may be too low.

Bed temperature

± 40 °C

Although not required, a heated bed aids in achieving better results consistently in comparison to not using one. Since E-PLA has a low vicat of 60 °C , then lower bed temperatures are sufficient to achieve bed adhesion and better bottom layer bonding.

Moisture & Storage

E-PLA is not highly hygroscopic and does not require specialised storage set-ups and can be stored in is original filament box, ideally in a sealed bag with a moisture desiccant.

Printing Checklist

Your First Layers

E-PLA has good inter layer bonding meaning that layer height adjustments mainly affect the aesthetics of the model.

Speeds

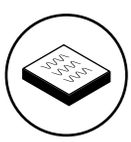
There are a number of printing speeds that can be adjusted for the printing process with E-PLA which will reduce lead times but can reduce print quality. After gaining experience, this can help you determine how to achieve the desired results at a shorter time frame.

Bed Adhesion

E-PLA adheres to the print surface easily. It is one of the few filaments that does so . It doesn‘t require a heated bed but it is recommended due to it helping to stabilize the temperature evenly. This is very key in the early stages of the printing process. E-PLA doesn’t require a heated bed but it is recommended to use one at temperatures between 40-60 °C.

Bed Adhesion Options

BUILDTAK SURFACE



HEATED BED

Summary and Notes

1. E-PLA doesn’t require a heated bed but it is recommended To use one at temperatures between 40-60 °C

2. E-PLA has a vicat of 60 °C which is low and means high temperatures affect it more than other filaments.

3. Ensure the extruder heights are optimum, otherwise you will get over/under-extrusion issues.

Skirt / Brim

Not require, but helps to reduce issues for larger parts.

Support Material

PVA or E-PLA breakaway

Priming Pillar

Used when printing scaffold support or two colour models.

E-PLA

INDUSTRY EXAMPLE PRINT

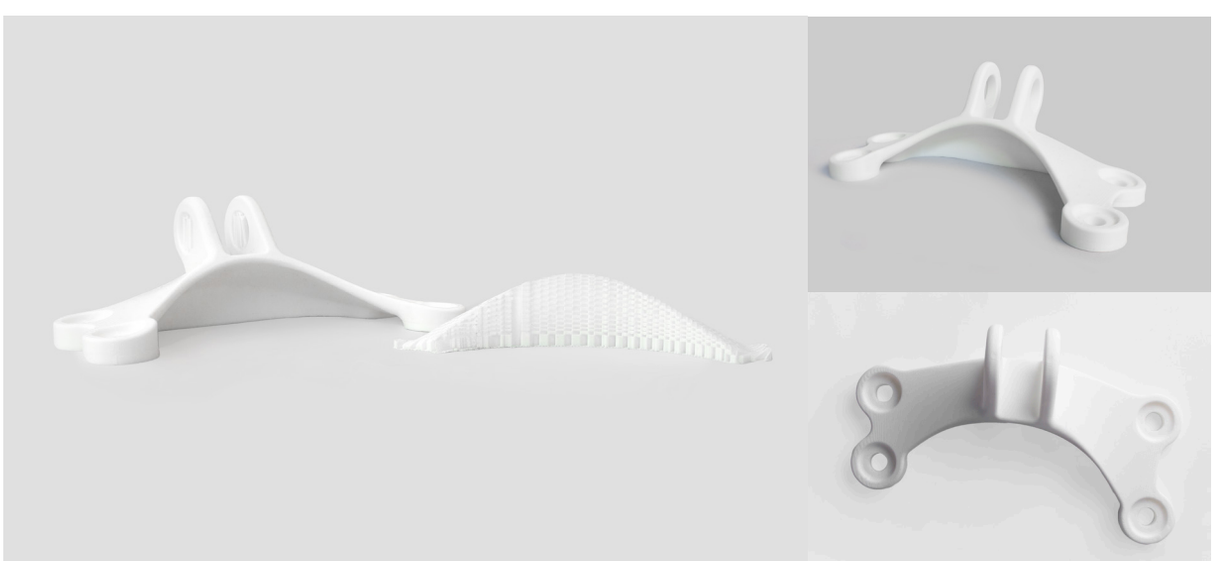
Aircraft Bracket 3D Model

E-PLA parts are a great way to test out the aesthetics of a part. Once printed, parts can be easily painted to create parts with good tolerances to check fit and form for any project.

The part seen here is a topology bracket for a aircraft which was printed using a breakaway support that was easily removed with a pair of pliers.

E-PLA is a good filament to test out various designs and how they can fit together to create a final product. It is easy to print and users can create many parts quickly using mirror mode on the Bolt Pro which can print two parts at once.

TOPOLOGY OPTIMIZED BRACKET

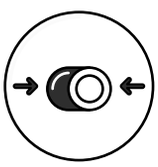


ACRYLONITRILE BUTADIENE STYRENE (ABS)

ABS filament is widely used already in standard manufacturing and this is due to it being high durable and with added strength. It is used to create visual prototypes, functional prototypes, tooling and also moulds that can be burnt away.

Although popular, ABS does have some caveats that need to be taken into consideration. It produces fumes when melted and needs to be enclosed during the printing process. Additionally, it is highly prone to warping due to high shrinkage during cooling and requires a heated print bed.

WHY USE IT



Strength.

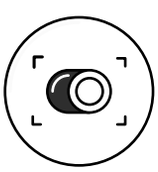
ABS offers great strength for parts and is often used to create tooling. It is more durable than E-PLA and is often chosen because of this despite it having more stringent print settings.

Heat Resistant

Another desired property that ABS offers is it is highly heat resistant, which makes it ideal for a wide range of engineering needs.

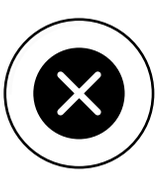
Impact Resistant

ABS offers parts that are less brittle than E-PLA parts. It is slightly more ductile, which creates parts that can withstand high impact situations.



Rigid.

ABS printed parts are also highly rigid and do not bend easily. This property compounded with its strength properties means that parts can withstand stresses far more than E-PLA.



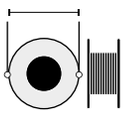
Disadvantage

ABS can warp significantly during the printing process. This is especially pronounced at the edges of your model as some areas cool faster than others which can pull the model of the print bed. This can be mitigated with proper adhesion techniques.

Disadvantage

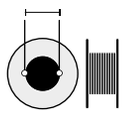
Due to shrinkage, ABS has lower dimensional accuracy in comparison to E-PLA or HIP for example.

SPOOL DIMENSIONS



Outer Diameter

200 mm



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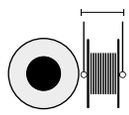
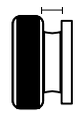


Width

54 mm



Thumbscrew Tension

3 mm

FILAMENT INFORMATION

Filament Diameter

1.75 mm(± 2%)

Filament Weight

750 g

Filament Length

200 mm

Specific Gravity

1.04 g/cm³

Available Colours

PRINTING & STORAGE

Extrusion Temperature

±230 °C

ABS requires higher temperatures to be extruded. It is more sensitive to temperature during the printing process. One thing to note is ABS produces fumes when heated and requires printing with the enclosure closed.

Bed temperature

± 90 °C

ABS has significant shrinkage when it is cooled. Because of this , it can causes warping where certain areas cool faster, shrink and pull on the layer structure when it is still molten. A heated print bed allows for these areas to remain temperature stable and reduces shrinkage.

Moisture & Storage

ABS is hygroscopic and requires to be stored away from open air. A good indication is if you print and are plagued with excess fumes and oozing. Storing it with Silica bags will aid in the removal of excess moisture in the air and if this is not possible, using an oven for 6-12 hrs at the stated temperature will help.

Printing Checklist

Your First Layers

Increasing layer height may produce more visible plateauing because the effect of increasing layer heights which in the same vain increases the extrusion volume. This therefore needs to be taken into consideration when printing smaller parts.

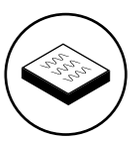
Speeds

There are a number of printing speeds that can be adjusted for the printing process. For ABS it is good to keep speeds consistent during the printing process which will improve print quality.

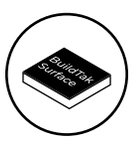
Bed Adhesion

To prevent ABS from warping, it is recommended to use strong bed adhesion methods. The addition of the flex-plate gives you the feature of easily being able to remove parts without damage. Printing larger parts can also face significant warping, therefore the best approach is to print parts using the enclosure after you ensure that the first layer is optimised. This will involve accurate bed levelling and using skirts and brims to help check that the extrusion process is proceeding accordingly.

Bed Adhesion Options



BUILDTAK SURFACE



HEATED BED

Summary and Notes

1. ABS absorbs moisture from the air and needs to be stored in an airtight enclosure such as a plastic bag or a professional filament storage system. Not doing so will lead to oozing and messy prints as the moisture evaporates from the filament during the extrusion process.

2. Always print ABS parts enclosed. This reduces temperature fluctuations during the printing process and aids in reducing issues such as warping and cracking.

3. When printing with a support material, ABS goes best with HIPS due to the similar extrusion temperature. When printing is complete, HIPS is soluble in d-limonene and the model can be submerged in it where the HIPS dissolves leaving your print.

4. ABS Is UV sensitive, so store both the filament and printed parts away from direct sunlight.

✓ **Skirt / Brim**
Recommended for ABS parts, both large and small.

✓ **Raft**
For large surface area parts.

✓ **Support Material**
HIPS and break-away ABS

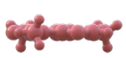
✓ **Priming Pillar**
Required when using two materials such as HIPS for ABS.

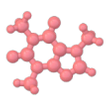
INDUSTRY EXAMPLE PRINT

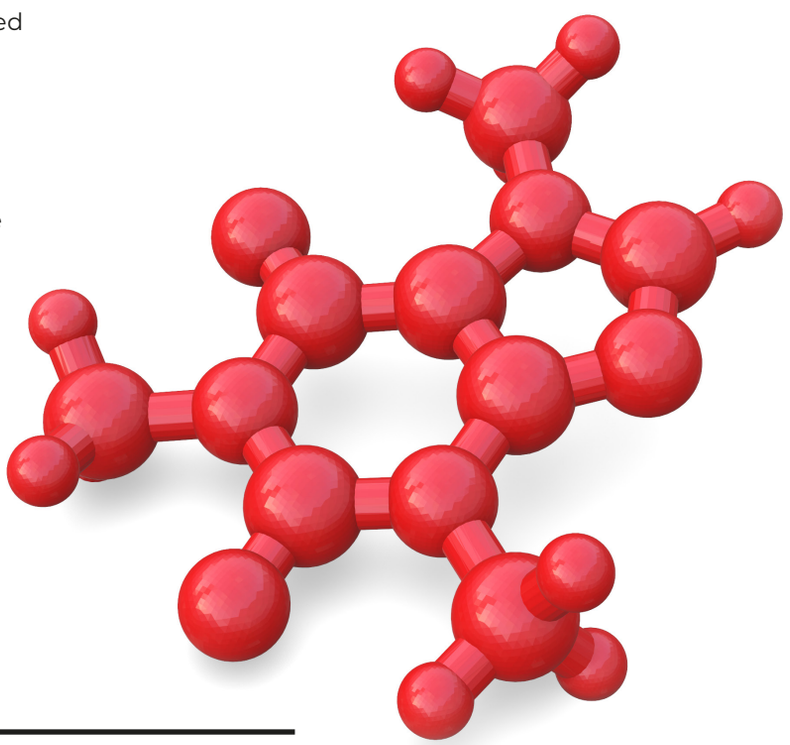
EDUCATIONAL MOLECULE PRINT

The model here was printed with ABS and HIPs as a support material. Although it is great for functional prototypes, it is also effective for visual parts because it can be post processed to achieve better visual fidelity.

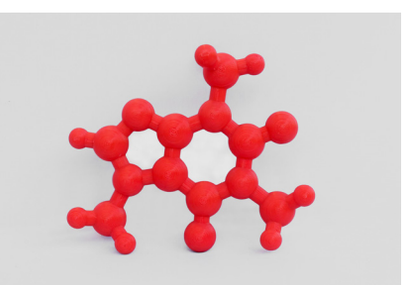
Parts can be dropped and withstand various stresses which is great for long lasting prototypes or in this case a part that can be used for education demonstrations where it would likely face some wear and tear.







Molecule 3D Model

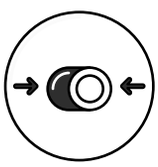


POLYETHYLENE TEREPHTHALATE + Glycol (PETG)

PETG is a very durable and a great material for a wide range of engineering requirements. Outside 3D printing, it is the most widely used plastic that is often used to create plastic liquid bottles.

This is due to its great ability to last and withstand abrasion. It offers parts that are strong and when printed with less infill, the parts are slightly flexible just like standard water bottles.

WHY USE IT



Strength.

PETG is very strong and this allows it to withstand high pressures in comparison to other filaments. This is especially pronounce in load bearing applications.

Chemical Resistant

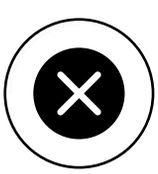
Considering its use in the creation of various containers, PETG is not affected by a wide selection of chemicals and this property is useful in certain engineering projects.

Impact Resistant

PETG has very high impact resistant properties with the added benefit of being ductile. This means its less brittle than ABS/E-PLA and won't break easily if a force is applied.

UV Resistant

In contrast to ABS, PETG parts aren't affected as much by UV radiation and can withstand it better.



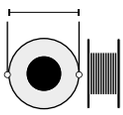
Disadvantage

Although strong, PETG parts scratch easy in comparison to other materials like PP.

Disadvantage

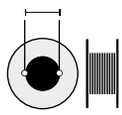
PETG can string a lot during the printing process.

SPOOL DIMENSIONS



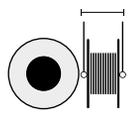
Outer Diameter

200 mm



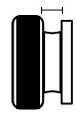
Centre Hole Diameter

52 mm



Width

54 mm



Thumbscrew Tension

3 mm

FILAMENT INFORMATION

Filament Diameter

1.75 mm(± 2%)

Filament Weight

750 g

Filament Length

218 mm

Specific Gravity

1.27 g/cm³

Available Colours

PRINTING & STORAGE

Extrusion Temperature

±230 °C

PETG has a relatively high melting temperature. When it is molten, it has more elasticity properties than other non flexible filaments.

Bed temperature

± 70 °C

PETG may have adhesion issues with standard beds, therefore it is recommended to use a heated bed. This will ensure proper adhesion and reduce warping during the process. To aid with adhesion, using a brim can help reduce possible warping especially with large surface area parts.

Moisture & Storage

PETG is highly resistant to liquids but with any filament, it is best to store it sealed away to ensure best quality.

Printing Checklist

Your First Layers

Layer height for PETG is a dependent on the requirement of the model. Smaller layer heights improve the overall aesthetics of the object.

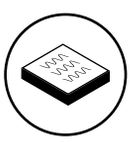
Speeds

Optimizing print speeds also can improve surface finish and how glossy the model becomes. PETG is prone to oozing and stringing therefore slower speeds can help. Furthermore, it is difficult to get good bridging with PETG because of this and needs to be taken into consideration.

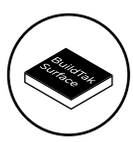
Bed Adhesion

As mentioned earlier, PETG requires a higher gap between nozzle and print bed otherwise the filament can get dragged around and cause issues.
Additionally it is recommended to use extra adhesion products to reduce the affects of shrinkage as the part cools. Larger parts with large surface areas can warp at the corners, therefore adhesion is key in these use cases.

Bed Adhesion Options



BUILDTAK SURFACE



HEATED BED

Summary and Notes

1. Keep PETG dry before the printing process to reduce issues early on. A good habit to practice is to store most of your filaments with silica bags for added protection if a dry store environment is not possible.

2. PETG is prone to stringing, oozing and blobbing, therefore,this should be the main factors to mitigate when printing.

3. The best methodology with PETG is to print with slower first layer speeds which will help with better bed adhesion.

Skirt / Brim
Not require, but helps reduce printing issues

Support Material
PVA or PETG breakaway.

INDUSTRY EXAMPLE PRINT

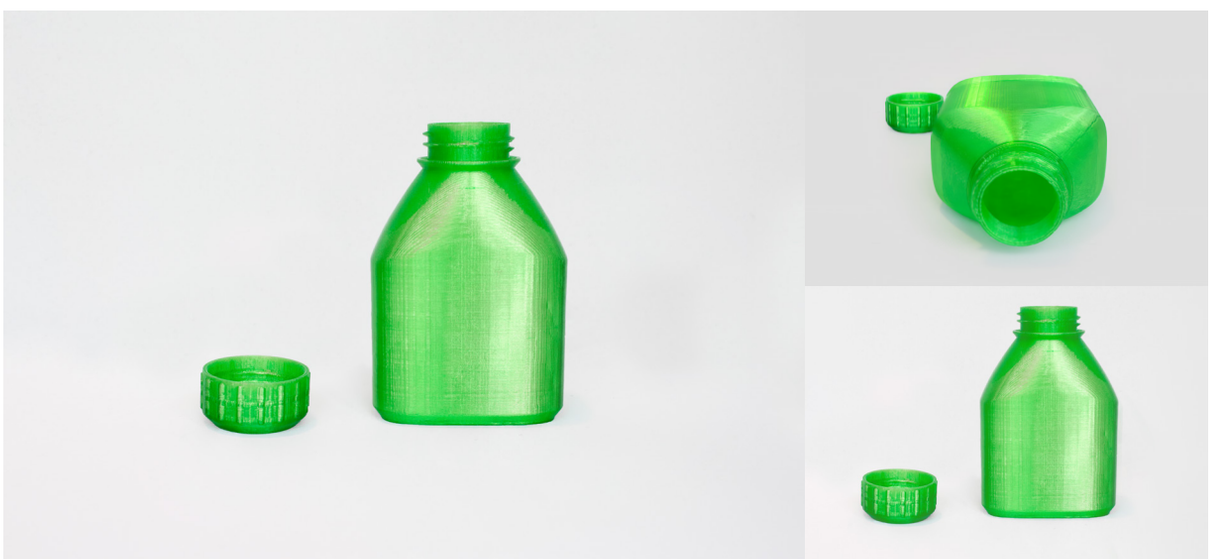
FUNCTIONAL PROTOTYPES

PETG is most associated with the production of bottle or containers because of its great chemical resistant properties. Apart form that however it has many other uses cases.

One use case is to print outdoor brackets for various applications where a part is needed to withstand the effects of wear and tear where other thermoplastics would degrade rapidly if exposed to similar conditions.

Furthermore, it can also be used to create snap to fit components because PETG is ductile, especially when parts are thinner, while increasing infill makes it more stiff and rigid.

Medicine Bottle 3D Model

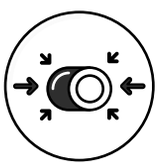


NYLON FILAMENT (POLYMIDE)

Nylon filament is a material that offers high durable and strong printed parts. Additionally, when printed at lower infill amounts, it can create slightly flexible parts.

Although similar to PETG, it offers far greater durability for engineering functional parts with the slight advantage of offering very low coefficient friction parts.

WHY USE IT



Strength & Durability

Nylon is one of the strongest and most durable filaments on the market. It offers parts that can resist wear and tear and also offer great tensile strength.

Low Friction

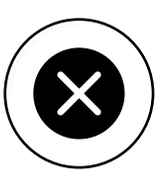
Having a low coefficient of friction means that Nylon is a great material for producing parts like gears or parts that require motion.

Impact Resistant

Nylon parts have great impact resistance and can absorb impact forces with minimum deforming. They give users versatile options for prototyping applications.

Heat Resistant

Nylon allows for the creation of various engineering parts that can withstand high temperatures. Combining this attribute with the low friction feature can create strong functional prototypes.



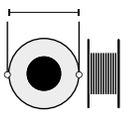
Disadvantage

Achieving optimum bed adhesion can be challenging when printing with Nylon.

Disadvantage

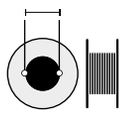
Nylon is highly hygroscopic which will affect print quality if the filament is not dried properly.

SPOOL DIMENSIONS



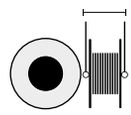
Outer Diameter

200 mm



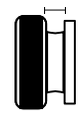
Centre Hole Diameter

52 mm



Width

54 mm



Thumbscrew Tension

3 mm

FILAMENT INFORMATION

Filament Diameter

1.75 mm(± 2%)

Filament Weight

750 g

Filament Length

193 mm

Specific Gravity

1.08 g/cm³

Available Colours

PRINTING & STORAGE

Extrusion Temperature

±250 °C

Nylon has a high extrusion temperature but be mindful of this since it can string and ooze more if the temperature is too high. If the temperature is too low, then it will have trouble adhering to the print bed.

Bed temperature

± 90 °C

Due to its material properties, Nylon does not adhere well with most surfaces including BuildTak and needs higher heated bed temperatures.

Moisture & Storage

If Nylon filament is not stored correctly, printed models will have a rougher texture and you may face lots of oozing. You may hear popping or cracking sounds that indicate that it has absorbed too much moisture.

Printing Checklist

Your First Layers

Nylon does not have any layer height requirements apart from aesthetics. However, Nylon parts can crack, therefore increasing the shell layers can help reduce this.

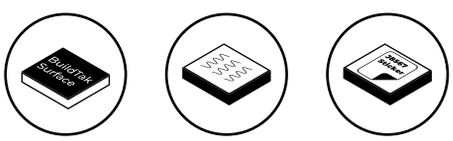
Speeds

Nylon can warp and crack during the printing process and this can be reduced if inter layer bonding is increased. This is done with slower printing speeds that gives the filament time to bond correctly. Printing at higher speeds can create print failures more often.

Bed Adhesion

Nylon can warp significantly during the printing process and requires J8567 stickers to keep the first layer stuck to the build-plate. This issue also transfers to the later stages of the printing process and can lead to cracking as some layers peel away from others. To reduce this issue, we recommend printing with the enclosure closed to reduce temperature changes and prevent cracking.

Bed Adhesion Options



BUILDTAK SURFACE | HEATED BED | J8567 STICKER

Summary and Notes

1. Nylon is hygroscopic and absorbs moisture which can affect the print quality considerably.

2. To reduce possible cracking issues, print with the enclosure to help keep the temperature in the printer stable.

3. As a reminder, achieving adhesion is challenging depending on the print model so ensure the heated bed is set at 90 degrees and to use the J8567 sticker .

Skirt / Brim

Not required, but helps to reduce issues, for larger parts.

Support Material

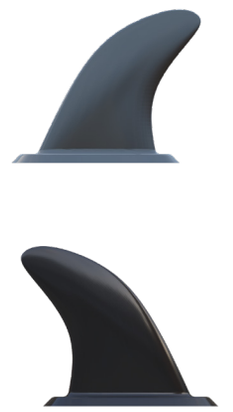
PVA or NYLON breakaway.

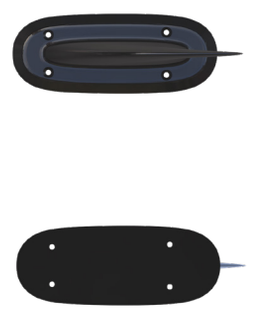
INDUSTRY EXAMPLE PRINT

SPORT INDUSTRY PRINT

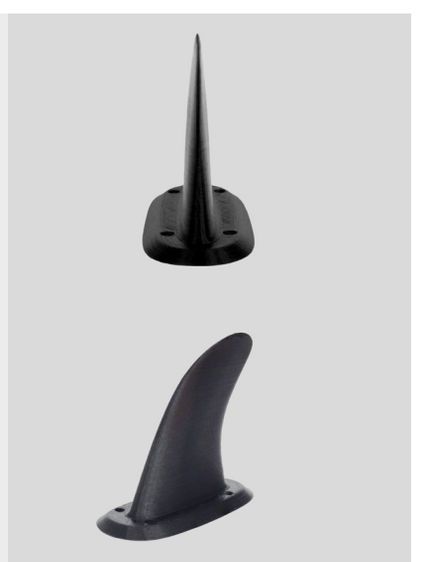
As mention, Nylon parts have very low friction properties making it a great choice for a surfboard fin prototype.

A part printed with Nylon also has the added benefit of being able to withstand high stresses which makes it ideal for tooling and functional parts that can be tested to gauge how well a design can perform.





Surfboard Fin 3D Print

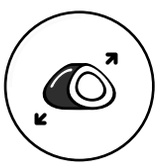


FLEX FILAMENT (TPU)

Flexible filament (TPU) is created by combining a standard polymer with rubber. This creates a filament that is very similar to what is used in standard manufacturing for parts in automobiles and many household items.

The printed objects that can be created are not only flexible, but have higher elasticity than most of the other slightly flexible filaments available.

WHY USE IT



Elastic

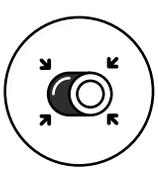
TPU parts are both highly elastic and flexible which offers a unique combination of 3D printing applications for both visual and functional prototypes.

Chemical Resistant

Parts produced with TPU are resistant to most standard chemical solutions which opens it up for a range of uses to create long lasting parts.

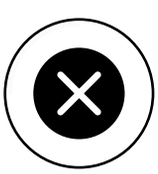
Impact Resistant

Flex parts are highly impact resistant due to its elastic rubber like properties.



Heat Resistant

Due to its abrasion resistant properties, coupled with the elasticity, flex parts will last and endure various stress depending on the build direction.



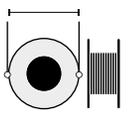
Disadvantage

TPU is challenging to print with because it strings significantly and can ooze. This is due to its elasticity properties making it harder to work with.

Disadvantage

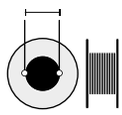
TPU prints cannot be post processed after printing which can be a minus for visual prototypes.

SPOOL DIMENSIONS



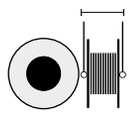
Outer Diameter

200 mm



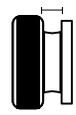
Centre Hole Diameter

52 mm



Width

54 mm



Thumbscrew Tension

6 mm

FILAMENT INFORMATION

Filament Diameter

1.75 mm(± 2%)

Filament Weight

750 g

Filament Length

218 mm

Specific Gravity

1.27 g/cm³

Available Colours

PRINTING & STORAGE

Extrusion Temperature

±230 °C

Printing with Flex may involve some testing with the optimum temperature. Due to its properties, it may string if the temperature is to high and create messy prints.

Bed temperature

± 70 °C

Flex filament may face some adhesion issues when printing and requires a relatively hot heated bed to ensure the filament stays on the print surface.

Moisture & Storage

TPU absorbs moisture very easily and requires drying before printing. Additionally using a poly-box during the printing process will also aid in keeping the material dry during the printing process which is crucial for parts that require longer lead times.

Printing Checklist

Your First Layers

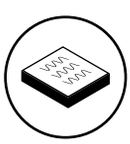
TPU is a challenging material to print with. It has higher risk of being plagued with blobs and oozing which can create rough parts. Additionally, it has poor bridging characteristics and prints better with objects that require consistent extrusion where there are less stops and starts of the extrusion process.

Speeds

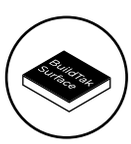
TPU prints better with slow speeds. This again is due to its ability to stretch without breakage when molten which causes oozing and stringing. Faster speeds can lead to this and slower speeds allows the material to adhere better and settle per layer .

Bed Adhesion

Flex filament can warp if there is no heated bed used at relatively high temperatures reaching at least 70 °C. Although it doe not warp as much as ABS and has more stringing issues, the usage of effective bed adhesion for the first few layers is a good indication how the printing process will go.



BUILDTAK SURFACE



HEATED BED

Summary and Notes

1. Keep Flex dry and additionally, dry it further in the oven for 6-12 hours below 55 °C to ensure that most of the moisture in the filament is gone.

2. Printing with TPU requires printing with consistent flow rates because the material is sensitive due to its elastic properties.

3.Flex Filament strings a lot due to it being highly viscous when molten and it will ooze out of the nozzle as the extruder travels.

4. TPU is best used with models that require long periods of extrusion. This means simple parts that do not have complex features on the surface. Models that will require lots of travel movements for the extruder will result in lower print quality.

Skirt / Brim/ Raft

Not require, but helps reduce issues, for larger parts.

Support Material

PVA

INDUSTRY EXAMPLE PRINT

PRODUCT ACCESSORIES PROTOTYPES

TPU is often used to create parts that need to be elastic. One great use case is printing phone covers but it can also be used on other industries for example in the creation of car panel designs, shoe designs and for medical devices.

Surfboard Fin 3D Print

POLYPROPYLENE FILAMENT

PP is a recent addition in the 3D printing world and offers some unique properties that make it an important material for engineering purposes.

It is a semi crystalline polymer which means on a molecular level, once the material cools, it retains its molecular structure which has attributes of added strength and durability.

If printed with lower infill settings, it can create flexible parts that have almost no bending failure properties, while increasing infill can create more rigid parts , but both types retain their material properties.

WHY USE IT

Heat Resistant

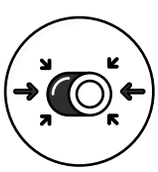
PP has great heat resistant properties meaning it is ideal for engineering applications. This mainly due to its melting temperature which is at 164 °C. Additionally, its vicat is at 85 °C where it is most pronounced.

Chemical Resistant

PP is not affected by most solvents and is often used to create containers for various chemicals.

Impact Resistant

Because off the semi-crystalline structure, PP is highly resistant to impacts. The flexibility features also make it useful since it is often used to create hinges in standard manufacturing.

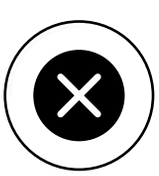


Durable, Strong & Lightweight

PP is highly resistant to wear and can create parts that do not erode easily with heavy use. Furthermore, parts created are strong while being lightweight.

Disadvantage

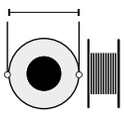
PP does not bond well with any other material and this means it is not possible to print with standard adhesion methods apart from PP based adhesive products



Disadvantage

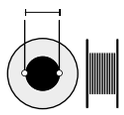
PP models cannot be post processed due to its adhesion issues.

SPOOL DIMENSIONS



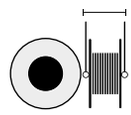
Outer Diameter

200 mm



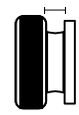
Centre Hole Diameter

51 mm



Width

72 mm



Thumbscrew Tension

6 mm

FILAMENT INFORMATION

Filament Diameter

1.75 mm(± 2%)

Filament Weight

500 g

Filament Length

233 mm

Specific Gravity

0.89 g/cm³

Available Colours

PRINTING & STORAGE

Extrusion Temperature

±220 °C

PP quickly settles back to its original molecular structure once it cools and therefore printing with it requires high temperatures. This ensures it flows smoothly during the printing process.

Bed temperature

± 80 °C

PP requires a heated print bed during the printing process. It cools and hardens quickly and a heated bed that reaches its vicat temperature ensures that adhesion is possible and improves the first layer adhesion process.

Moisture & Storage

PP is highly resistant to a lot of things . Although it is not hygroscopic its still recommended to store PP away from moisture. Keep your filament dry and away from direct sunlight.

Printing Checklist

Your First Layers

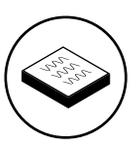
PP can warp significantly during the printing process. Using larger layer heights increase the likely-hood of this since at the edges, the stresses that are created as the material cools can cause more warping with larger heights. Smaller layers create less stress and improve interlayer bonding.

Speeds

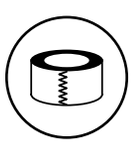
Printing with Polypropylene at higher speeds creates rough edges and parts that have poor adhesion between layers .Although this is true for all filaments, the effects are more pronounced with PP due to its material properties.

Bed Adhesion

Polypropylene is semi-crystalline which means it doesn't adhere to any other material well. This brings about a problem because it won't adhere to any print surface, other than its own. Therefore printing with PP requires the use of Tesa PP 57167 tape but not directly on the BuildTak Surface. Instead if you remove the Flexplate and flip it around and use the tape on the sheet metal side.



HEATED BED



TESA PP TAPE 57167

Notes

1. PP is prone to warping and requires smaller layer heights and slower printing speeds when creating a part. This will reduce warping due to smaller layers promoting better interlayer adhesion and also reduce the possible cooling stresses which cause warping or cracking.

2. Ensure that the first layer is flat by making the nozzle press the filament against the print bed. This will help model more uniform since PP can ooze during the process.

3. PP can crack or ooze if the cooling process is not uniform and using an enclosure will prevent different regions of the print from cooling non-uniformly.

4.Store PP in a seal bag to ensure it is dry as possible before the printing process.

Skirt / Brim/ Raft

Not require, but helps to reduce issues, for larger parts..

Support Material

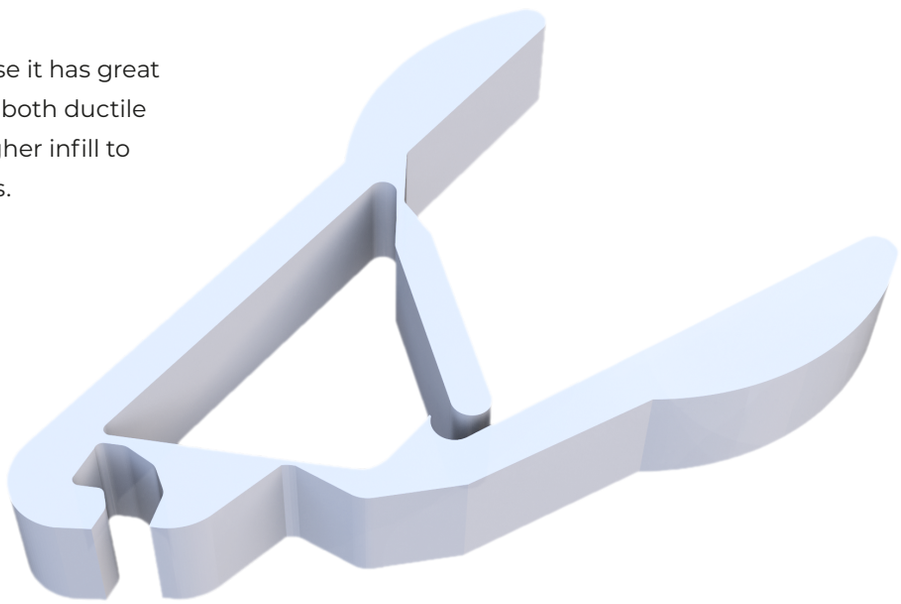
NONE

INDUSTRY EXAMPLE PRINT

TOOLING PRINT EXAMPLE

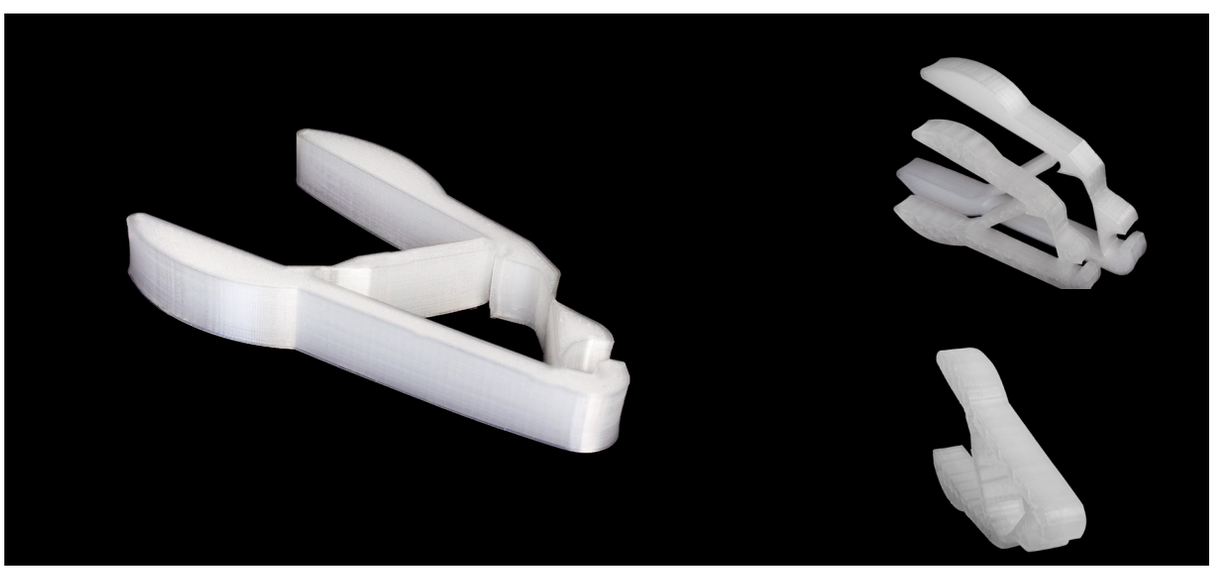
PP is very strong and durable plastic that has great fatigue resistant properties. For this model, we chose to print a compliant plier designed by BYU CMU which operates without the use of multiple parts to create a functional tool or part.

This is a great use case for PP because it has great wear and tear resistance and can be both ductile and more stiff when printed with higher infill to create a wide range of different parts.



BYU DESIGNED PLIERS

Under CC
Compliant Mechanisms



SCAFFOLD FILAMENT (PVA)

PVA is used as a soluble support material during printing complex parts. It works as a bridge material between open areas of the print which would otherwise deform.

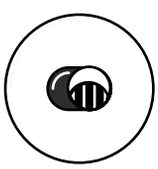
Although it is possible in slicer software to use the same material as support, this often requires extra post processing to remove the break-away support and with some objects, this can create rough 3D prints.

PVA gives more flexibility and options for complex parts and can aid in producing complex parts in one pass unlike other manufacturing processes.

WHY USE IT

Water Soluble

PVA is soluble in water which means post processing is relatively easy. Depending on the amount used, all that is needed is to submerge the model in water for a few hours and the PVA melts away.



Great for Overhangs

Parts that require large overhangs for example arches, will need the use of PVA to support the print.

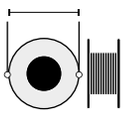
Disadvantage

PVA needs to be stored in a airtight container because it is highly hygroscopic which will make the printing process difficult.

Disadvantage

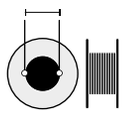
PVA can cause clogging of the nozzles during the printing process. This is especially pronounced when the printing process requires the heated extruder to remain stationary for long periods of time.

SPOOL DIMENSIONS



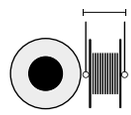
Outer Diameter

200 mm



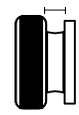
Centre Hole Diameter

52 mm



Width

65 mm



Thumbscrew Tension

6 mm

FILAMENT INFORMATION

Filament Diameter

1.75 mm(± 2%)

Filament Weight

500 g

Filament Length

188 mm

Specific Gravity

1.19 g/cm³

Available Colours

PRINTING & STORAGE

Extrusion Temperature

±215 °C

PVA extrudes at a temperature slightly higher than E-PLA which makes it the ideal material to use as for support. This is due to both materials being able to adhere to each other without issues. Larger temperature differences may cause issues when printing with support materials.

Bed temperature

± 40 °C

As mentioned before, PVA and E-PLA go well together and PVA adheres well with the print bed at around 40 °C.

Moisture & Storage

PVA is highly hygroscopic and this makes it prone to oozing during the printing process. This can affect your model significantly by blocking paths that the extruder has to work on and resulting in deformed parts.

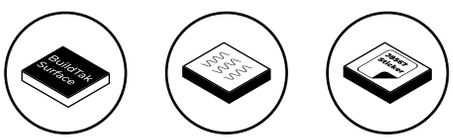
Printing Checklist

Prime Pillar

The purpose of a Prime pillar is twofold. It is a rectangular 3D part that is printed at the front of a model. It is only used when printing with two materials using the two extruder and is printed each time the extruder change. Its purpose is to prime the extruder to ensure they are properly heated and extruding properly. Additionally, it cleans the nozzles to remove excess dried filament, especially for material that oozes easily.

Bed Adhesion

PVA is not difficult to work with. It does not require any specialized adhesion methods when in use with a Buildtak Surface, however, the addition of sticky tape and a heated bed will help with adhesion.



BUILDTAK SURFACE

HEATED BED

J8567 STICKER

Summary and Notes

1. PVA works well with E-PLA and we have tested it with Flex with good results. Other high temperature materials may cause issues when printing due to the higher temperatures. If support is require, it is better to use HIPS or break-away support.

2. After printing, it is best to use a pair of pliers to remove the larger parts of PVA before soaking it in water.

3.Store PP in a seal bag to ensure it is dry as possible before the printing process.

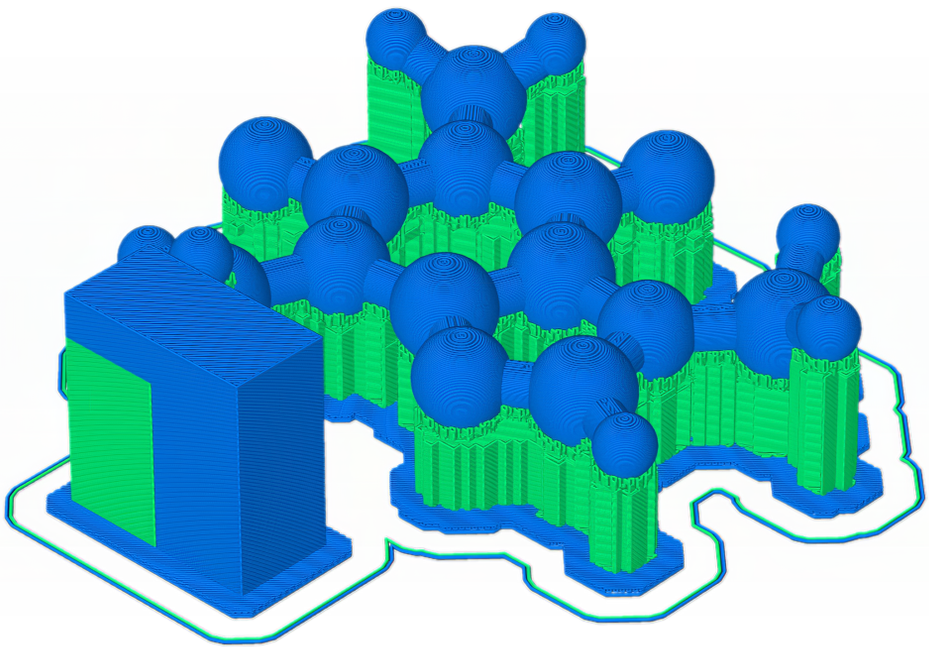
Prime Pillar
Recommended

Support Material for
1.E-PLA- Works well, especially for large parts
2.TPU-
3.PET/Co-polyesters

Skirt / Brim
Recommended

INDUSTRY EXAMPLE PRINT

MOLECULE STL WITH SUPPORT



E-PLA MOLECULE WITH PVA

HIGH IMPACT POLYSTYRENE FILAMENT (HIPS)

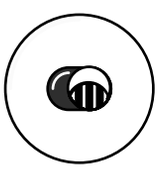
HIPS is a filament that can both be used as a support material and also to create 3D prototypes. In terms of mechanical properties, it is very similar to ABS where it is often used as a support material due to the similar temperature properties allow both materials to stick to each other.

With HIPS you can create parts with great dimensional accuracy and like ABS , it can be machined further or painted in the post processing stage.

WHY USE IT

Dissolves in D-Limonene

HIPS dissolves in citrus based acids like D-Limonene where it can be used as a support material for complex parts that are made from namely ABS.

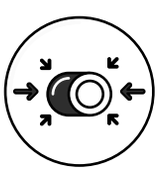


Great for ABS Overhangs

HIPS is a great support materials for complex ABS geometric 3D prints in the same way how PVA works well with PLA. This is due to it being able to adhere well to ABS during printing allowing for smooth parts once removed.

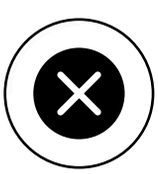
Impact Resistant and Easy to Print

HIPS is highly impact resistant and can be used to create proof of concept functional parts. HIPS creates great looking 3D prints and it is also inexpensive, which means it is ideal for rapid prototyping models.



Durable, Strong & Lightweight

PP is highly resistant to wear and can create parts that do not erode easily with heavy use. Furthermore, parts created are strong while being lightweight.



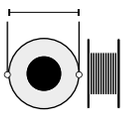
Disadvantage

HIPS can face warping issues that can make it challenging to print.

Disadvantage

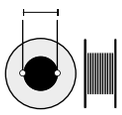
HIPS is hygroscopic and needs to be stored in a airtight bag.

SPOOL DIMENSIONS



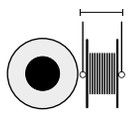
Outer Diameter

200 mm



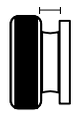
Centre Hole Diameter

52 mm



Width

54 mm



Thumbscrew Tension

3 mm

FILAMENT INFORMATION

Filament Diameter

1.75 mm(± 2%)

Filament Weight

750 g

Filament Length

168 mm

Specific Gravity

1.03 g/cm³

Available Colours

PRINTING & STORAGE

Extrusion Temperature

±230 °C

HIPS has a high melting temperature and this makes it a great support material for ABS parts which would normally melt PVA support.

Bed temperature

± 90 °C

HIPS can warp and in order to help it adhere to the print bed, a high temperature setting will allow it to remain fixed during the printing process.

Moisture & Storage

With any filament, it is highly recommended to store HIPS in a sealed bag since it will allow for the material to last and create better prints.

Printing Checklist

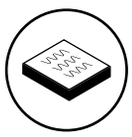
Prime Pillar

When using HIPS as a support material, the best process is to use a prime pillar which helps with ensuring extrusion settings and temperature settings are correct during each new layer pass. This is due to the switching of the extruder hot-ends for each new layer.

Bed Adhesion

HIPS has a low probability of warping in comparison to ABS but to reduce this, it is best to use the same adhesion steps as ABS.

BUILDTAK SURFACE



HEATED BED

Summary and Notes

1. HIPS can warp and requires using a heated bed and adhesive products to prevent it from warping or it from detaching from the print bed.

2. HIPS can also be used to create great looking parts and not only as a support material. If used as a support material, be sure to use d-limonene after printing to dissolve it away where your ABS model will remain.

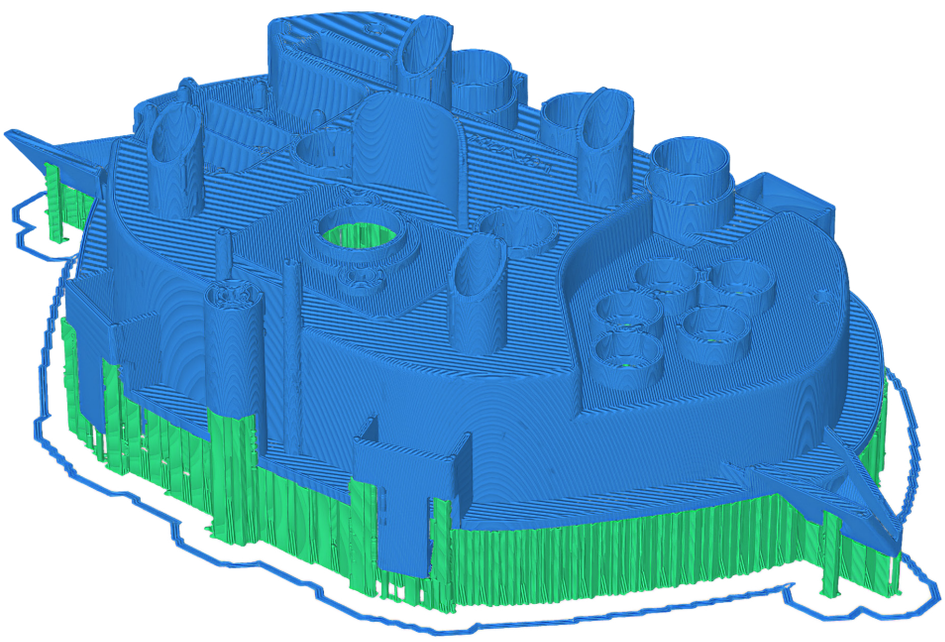
3. To get better results, print with the enclosure to ensure the print chamber temperature remains hot to prevent any temperature changes.

Prime Pillar
Recommended

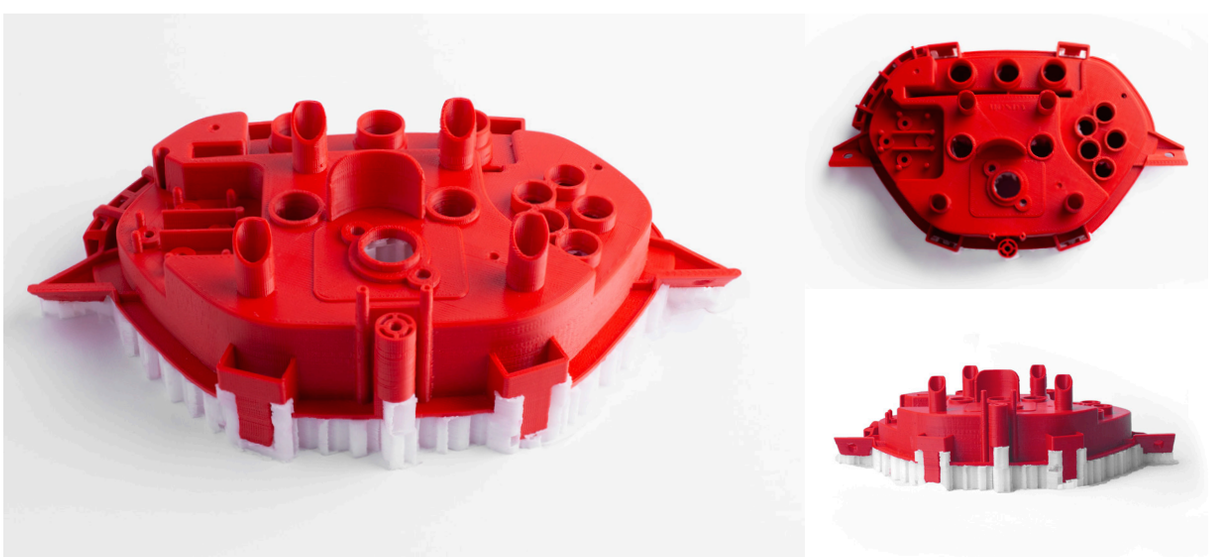
Support Material for
ABS

INDUSTRY EXAMPLE PRINT

ENGINEERING ABS PRINT WITH HIPS



HONDA ENGINE COVER WITH HIPS SUPPORT

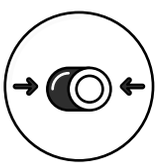


CARBON FILAMENT (PETG+Carbon)

One key distinction that needs to made is that Carbon filament is not the same as standard carbon fibre. Carbon filament is created by combining shorter carbon fibre with another common material like PetG which is then used to create the carbon filament spool. Despite this, the printed object still benefits from the strength properties while still remaining lightweight. It has improved tensile strength and can create really rigid parts.

One key note before printing is carbon filament requires the Bolt Pro NozzleX hot-ends which are abrasion resistant. Using standard nozzles will damage them and lead to clogging.

WHY USE IT



Strength

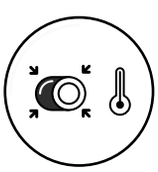
Carbon printed parts offer really high strength parts that are stiff and very rigid. These parts can be used with great effect for functional prototypes.

Light Weight

The added benefit of using carbon filament is in conjunction with the strength properties, parts are also extremely lightweight which opens up a wide range of use cases for engineering.

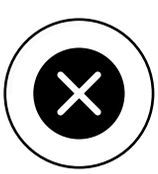
Impact Resistant

Parts produced with carbon filament have impact resistance which is comparable or even exceeds other printing materials in the market.



Durable and Heat Resistant

Unlike ABS and PLA, carbon printed parts have the additional benefit of being very abrasion resistant which offers longer lasting parts that look good and function well with great heat resistant



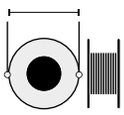
Disadvantage

Carbon filament is abrasives and can clog and ruin non specialised nozzles.

Disadvantage

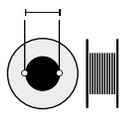
Carbon prints are an abrasive finish

SPOOL DIMENSIONS



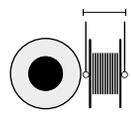
Outer Diameter

200 mm



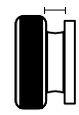
Centre Hole Diameter

52 mm



Width

54 mm



Thumbscrew Tension

3 mm

FILAMENT INFORMATION

Filament Diameter

1.75 mm(± 2%)

Filament Weight

500 g

Filament Length

164 mm

Specific Gravity

1.19 g/cm³

Available Colours

PRINTING & STORAGE

Extrusion Temperature

±230 °C

Since the carbon filament is mixed with PETG, the print settings mostly reflect the same setup. One thing to be mindful is carbon can clog a lot and requires specialised metallic nozzles.

Bed temperature

± 70 °C

The bed temperature settings are similar to PETG again as that is the base material in the filament spool and needs to be high enough to adhere properly to the build surface.

Moisture & Storage

Storage of carbon requires it to be sealed and stored away from sunlight to uphold its quality.

Printing Checklist

Your First Layers

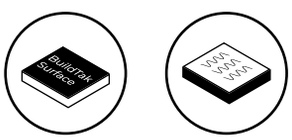
As with PETG, layer heights are highly dependent on the type of model that is being printed. This is mainly due to the combination of both materials that can create varying results during the printing process. Another matter to note is the size of the hot-end needs to be at least 0.4mm which is due to the carbon fibres that can build up with smaller nozzle sizes and create clogs during the printing process.

Speeds

Carbon prints work well with lower speeds and may not have the same fast speed settings that are available with filaments like ABS and PLA. This is mainly due to the fibres that can clog the extruder, especially if they build up.

Bed Adhesion

Carbon has an average chance of warping during the printing process and requires the printing environment to be enclosed to maintain a constant temperature. Using the Buildtak Flex Plate does aid in adhesion when printing and the use of other adhesives is not normally required.



BUILDTAK SURFACE

HEATED BED

Summary and Notes

1. Carbon filament can clog nozzles during the printing process and the best way to mitigate this is to use nozzle sizes of at-least 0.4mm.

2. Print with slower speeds when using carbon which is more prone to oozing and clogging.

3. Carbon filament can be brittle before the printing process and care handling and loading is required unlike other filaments.

Skirt / Brim/ Raft
Recommended

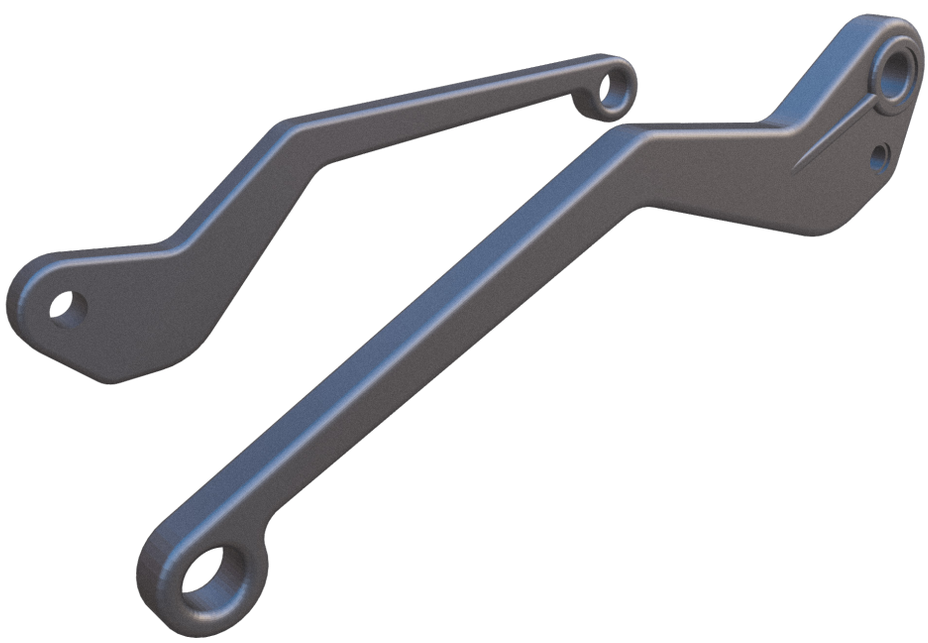
Support Material
PVA

INDUSTRY EXAMPLE PRINT

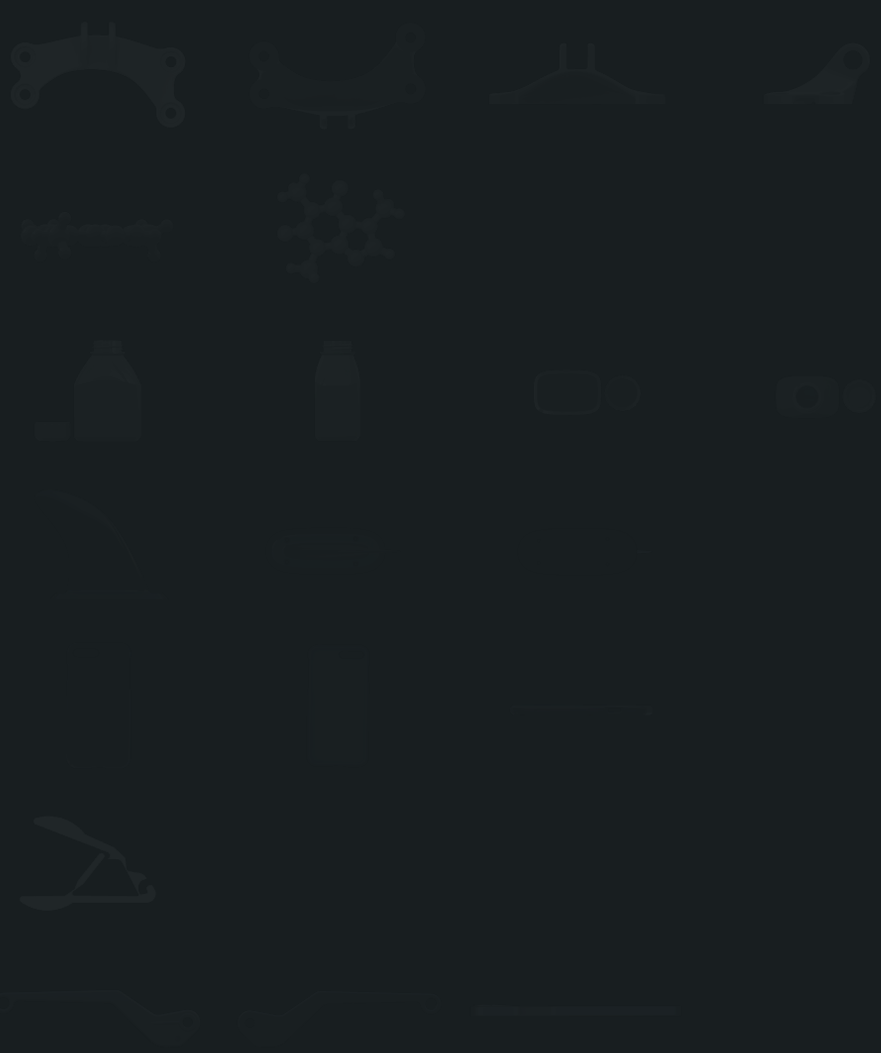
AUTOMOTIVE INDUSTRY PRINT

Carbon filament parts in 3D printing are often used as functional prototypes or as housings for models that may be inflicted with various impacts.

It is also often used to create levers because of its increased rigidity which is created from the small carbon bits added to the base material in the spool.



Motorcycle Lever Print



Leapfrog
3D Printers

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