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CREAT3D KNOWLEDGE HUB
TUTORIAL:
Selecting the right fibre for use in Markforged 3D printers

Markforged offers the unique capability to leverage continuous fibres to further strengthen and stiffen your 3D prints. It's a useful way to use plastic components in demanding applications, replacing the need for metal or other higher strength materials.

With a range of fibres available, as well as a number of ways to use fibre within a 3D print, it's important to select the right fibre and settings for the application. In this tutorial, we'll introduce the basics of fibre, cover the types of fibre fill available and breakdown the four Markforged fibres, their properties and when to use them.

A brief overview of fibre

Fibre, like many other strands of material, is strongest when loaded in tension. It will buckle, break or deform when bent or when under compression, but can handle far higher loads when in tension. In traditional engineering applications, materials like string, chain, wire and fibre are used in ways which take advantage of their tensile properties.

In Fused Filament Fabrication 3D printing, an extrusion of plastic is as strong as the molecular bonds holding it together. One way to enhance the properties of 3D printing plastics is to add filler materials into the base plastic, such as chopped carbon fibre into Nylon. This allows the stresses to be applied to the short, stiff fibres within the plastic. However, the overall strength is still defined by the plastic holding it together – which in the case of Markforged's Onyx material, is Nylon.

This is where we can apply continuous strands of fibre to further enhance a part's strength, stiffness or impact resistance. A continuous strand of fibre, where the fibres are joined at the atomic level, will be stronger than an extruded strand of filament comprising a mixture of chopped fibres and plastic.

We'll be looking at how to apply fibres like carbon fibre, fibreglass and Kevlar into 3D printed parts, to enhance part properties and leverage how these materials behave in tension.

Fibre fill options

Markforged's slicing software, Eiger, offers a few options for reinforcing parts with continuous fibre. Each reinforcement option can either be applied to individual layers or a group of layers within a part. Choosing one of these options is dependent on the application of your part and the specific loading conditions, as well as the part geometry - which brings with it some limitations. We cover more on this in our Using Fibre Tutorial.

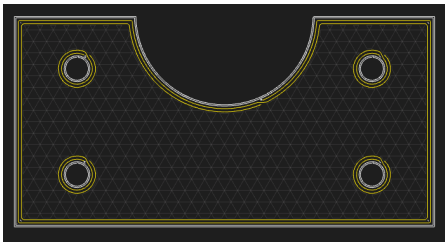
Concentric Fill

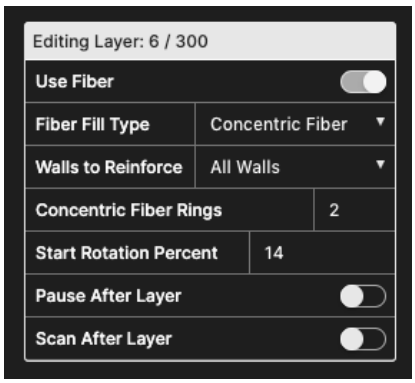
This type of fibre reinforcement lays strands of fibre around the perimeter of a part's walls. It is best used when a part needs to resist bending about the Z axis and strengthens the walls against deformation. Once you have selected Concentric Fill, you have the option to adjust where the rings of fibre are going to be placed:

- All walls: Fibre is laid around the perimeter of the outer walls and any internal holes
- Outer shell only: Fibre is laid around the perimeter of the outer walls only. This can be used to reinforce the part for bending or impact loads applied from the sides
- Inner holes only: Fibre is laid around the internal walls of the part only. This is a useful tool for applications where you need to strengthen through holes, bolt holes and other cavities. This improves load distribution when compressive or torsional forces are applied to these cavities or holes

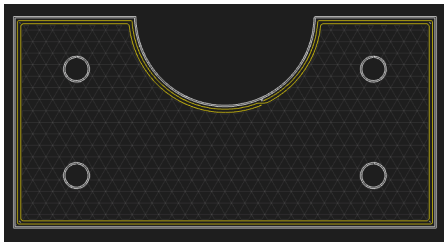
Concentric Fill

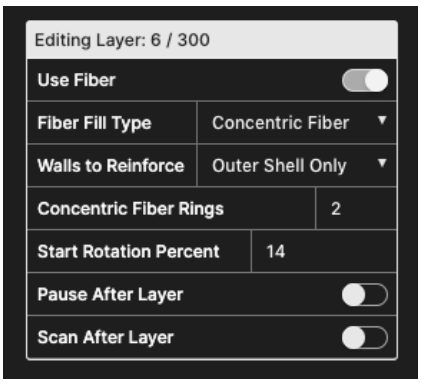
All walls



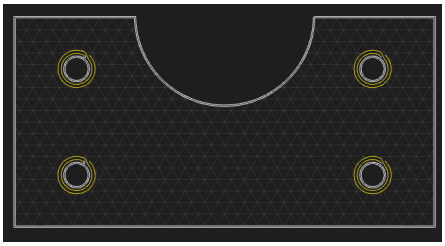


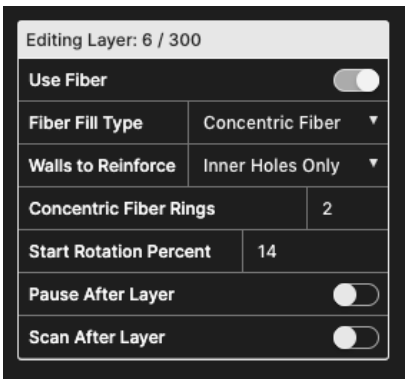
Outer shell only





Inner holes only

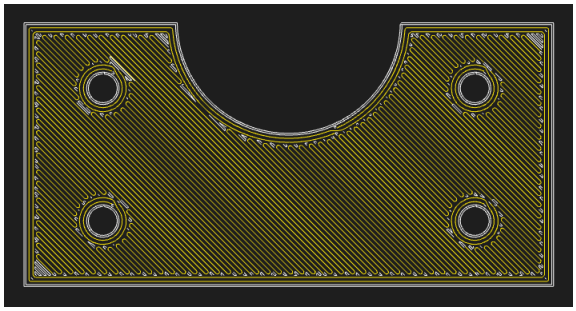


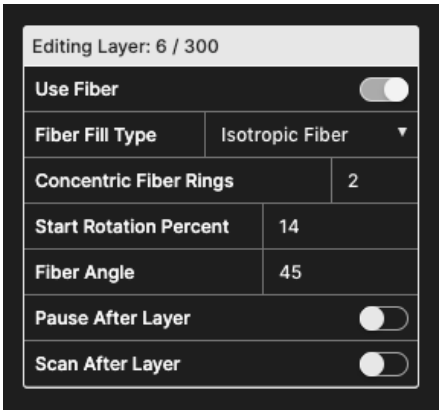


Isotropic Fill

This type of fibre reinforcement lays fibres in a zig-zag pattern, back and forth over an entire layer or group of layers, to simulate traditional composite lamination. By default, Eiger software will lay subsequent layers of isotropic fibre at 45 degrees to the previous layer, achieving unidirectional strength within a fibre group. This fibre strategy is best used when a part needs to resist bending in the XY plane (parallel to the build plate or the base of the printed part). In addition to the zig-zag layering, Isotropic fill will lay in rings of concentric fibre to also improve the wall strength.

Isotropic Fill





Choosing the right fibre for your application
Choosing fibre will depend on the application of your part and how it needs to behave under the loads and stresses it may experience. There are four type of fibre available on the Markforged printers, each with their own advantages and disadvantages, depending on the application and loading conditions of the part you are printing.

- **Carbon Fibre**

Printed on the Markforged X7 Industrial 3D Printer and Markforged Mark Two Desktop 3D Printer.

Carbon fibre has the best strength to weight properties of all the fibres available on the Markforged printers. It has a high stiffness and minimal deflection, and will remain close to rigid until failure, at which point it will often fracture. It has a tensile modulus similar to that of Aluminium and a stiffness of around 24 times that of ABS. This fibre is best used in constant loading conditions with a known force. Some use cases include those where Aluminium may have been previously used. Due to Carbon Fibre's high strength to weight ratio, you have the ability to match the strength of metal at a fraction of the weight.

- **Kevlar**

Printed on the Markforged X7 Industrial 3D Printer and Markforged Mark Two Desktop 3D Printer.

Kevlar is a shock-resistant material ideal for impact loading and resistance, and any cases where abrasion resistance is required. It has the least catastrophic failure mode of all the Markforged composite fibres, and will fail by bending until it eventually permanently deforms, without snapping.

- **High Strength High Temperature (HSHT) Fibreglass**

Printed on the Markforged X7 Industrial 3D Printer and Markforged Mark Two Desktop 3D Printer.

HSHT Fibreglass is a heat-resistant fibre, with the highest heat-deflection temperature (150°C) of all the Markforged composite fibres. This means that it can retain its strength at high temperatures and

is less susceptible to thermal effects. Along with this it has high elastic deformation properties and will deflect as it's loaded and then return to its original shape. HSHT will bend until it fractures.

- **Fibreglass**

Printed on the Markforged X7, Markforged X5, Markforged Mark Two and Markforged Onyx Pro 3D Printers.

Fibreglass is a cost-effective fibre, offering robust reinforcement with some flex and energy retention. It is 3 times stronger and 11 times stiffer that ABS. It's ideal for intermittent loading conditions and similar to HSHT, will bend until it fractures. It is also the most cost-effective of all the Markforged composite fibres.

	Properties	Failure behaviour	Ideal loading type	Common Applications
Carbon fibre	- High stiffness - High strength to weight - Minimal deflection	- Stiff until fracture	Constant loading	Applications include inspection fixtures, machining fixtures, cantilevered beams and any end-use parts that are subject to constant loading
Kevlar	- Tough and durable - Impact resistant - Good abrasion resistance	- Bends until deformation - Most predictable and forgiving failure mode	Impact loading	Applications include robotic arm grippers and end effectors, as well as lightweight jaws that need to withstand repeated clamping forces
HSHT Fibreglass	- Retains strength at high temperatures - Robust and sturdy - High elastic deformation properties	- High energy absorption until fracture	Constant loading at high temperatures	Common applications include weld fixtures, thermoforms, thermoset moulds, and blow moulds
Fibreglass	- Robust and sturdy - Cost-effective	- Bends until fracture	Intermittent loading	Common applications include functional prototypes, brackets, drill jigs, and soft jaws

Top Fibre Tips

- Identify the following for your part:
  - Environment and application
  - Loading conditions
  - Failure behaviour

- Match loading and environment requirements with the fibre properties
- Choose the most appropriate fibre fill type for your part, based on the loading conditions
- Choose Carbon Fibre for the stiffest part, where you require the highest strength to weight
- Choose Kevlar for when you require impact and abrasion resistance
- Choose HSHT Fibreglass if your application requires retention of strength at higher temperatures
- Choose Fibreglass for general applications and intermittent loading conditions

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