Guide to
Forged carbon

From concept to composite
2024

GUIDE TO FORGED CARBON FIBER WRITTEN BY BRENT CORNELIS IN COLLABORATION WITH UGHENT UNIVERSITY

GHENT
UNIVERSITY

Brent Cornelis

Welcome to my guide to forged carbon fiber

THIS GUIDE IS BORN FROM AN ITERATIVE PROCESS TRYING TO BETTER UNDERSTAND FORGED CARBON, IT HAS BEEN DISTILLED INTO ESSENTIAL KNOWLEDGE AND CONCISE CHECKLISTS. IT REPRESENTS A JOURNEY OF DISCOVERY, EXPERIMENTATION, AND REFINEMENT, WITH THE AIM OF MAKING YOUR EXPERIENCE AS STRAIGHTFORWARD AND REWARDING AS POSSIBLE. THIS GUIDE AND THE ACCOMPANYING VISUALS ENSURE YOU'RE WELL-EQUIPPED TO EMBARK ON YOUR OWN PROJECTS WITH CONFIDENCE AND CLARITY.

Table of Content

Intro

Basic introduction to forged carbon

The emergence of forged carbon fiber, a novel technique in carbon fiber manufacturing, represents a significant shift from traditional practices. Unlike conventional methods that employ continuous long fibers or woven sheets, forged carbon fiber utilizes shorter, chopped fibers mixed with a matrix like epoxy resin. This mixture is then compression-molded under pressure, allowing for a more randomized fiber orientation.

While forged carbon fiber may not reach the high strength-to-weight ratios of its traditional counterparts, it excels in molding complex shapes and offers a unique aesthetic appeal with its distinctive marbled appearance. This technique simplifies the manufacturing process, making it more cost-effective and less labor-intensive for certain applications. It opens up new design possibilities across various industries, including automotive and luxury goods, by combining performance with visual distinctiveness.

As development continues, optimizing the properties of forged carbon fiber through adjustments in fiber length, matrix composition, and processing techniques remains a focus. This advancement in carbon composites technology broadens the scope of application and highlights forged carbon fiber as a versatile and attractive material choice for the future.

Introduction to the guide

This guide is all about taking you through the process of working with forged carbon fiber, showing you how to use this material for your own projects. We start with the basics—why you might choose forged carbon and what to consider before diving in, like its strengths and weaknesses and the safety precautions you should take.

Stage 01 Why forged carbon?

Making an informed and responsible decision to use forged carbon is critical.

Stage 02 Before you start

Listed here is a checklist of everything you will need to complete a forged carbon project.

Stage03 Part Design

First up, we look at designing your piece. You'll see how to plan your design with forged carbon in mind.

Stage 04 Mold Design

Then, we cover how to design the mold that'll shape your part. This step is key to making sure everything fits and works as expected.

Stage 05 Slicing

Here, we prepare your mold design for 3D printing, focusing on getting all the details right.

Stage 06 Mold Preparation

We'll get the mold ready for the actual molding process, making sure it's clean and set up correctly.

Stage 07 Molding

This is where your project really starts to come to life as we mix the fibers with resin and mold them into shape.

Stage 08 De-molding

Carefully removing your piece from the mold comes next. It's a delicate step that can make a big difference in the final look.

Stage 09 Post-processing

After the piece is out of the mold, we'll show you how to clean it up and add those finishing touches.

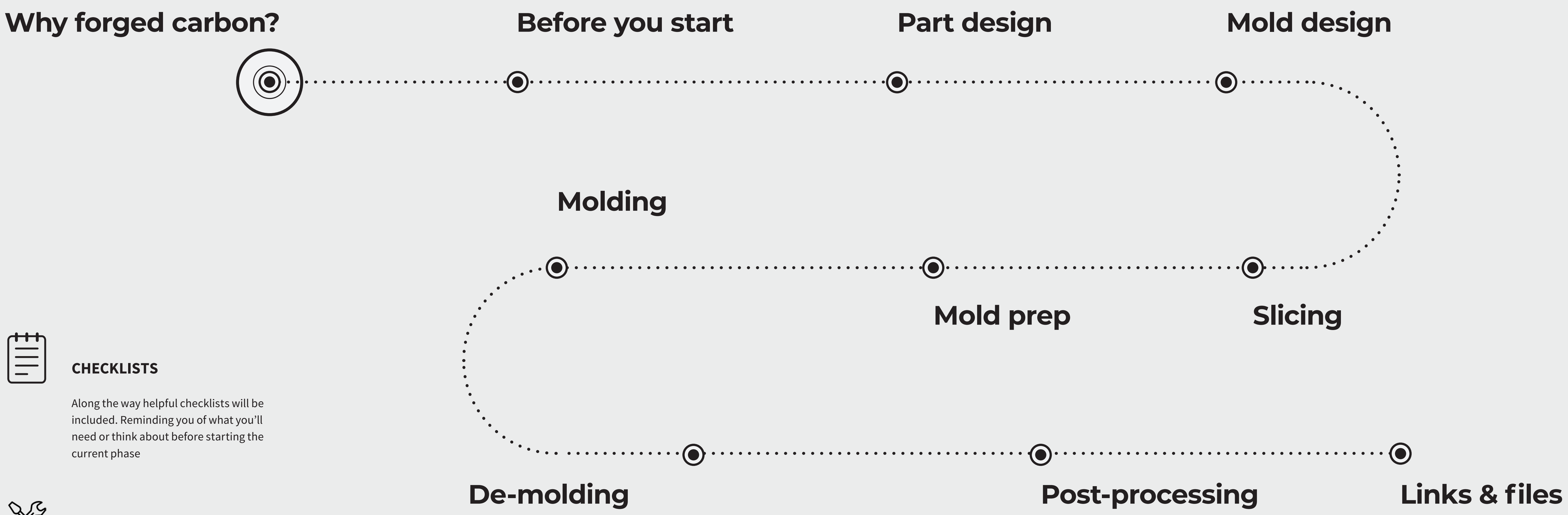
Stage 10 Links & files

Some helpful links and files to make the process easier.

This guide is more than just instructions. It's about giving you the room to try things out and make these projects your own. Sure, we'll give you the roadmap, but feel free to take detours, experiment, and really own your creations. Whether you're making something practical or just for fun, this guide will help you get there, offering the basics and encouraging you to put your own spin on things.

Make it your own

Journey/Stages



CHECKLISTS

Along the way helpful checklists will be included. Reminding you of what you'll need or think about before starting the current phase

TOOLS

In some stages, tools / files will be included. You can download these via scanning the QR-code to github or thingive

Stage 01
Why forged carbon?

When to use

Responsible use of forged carbon fiber

Forged carbon fiber, esteemed for its captivating appearance and unparalleled mechanical attributes, is increasingly favored for prototyping and addressing specific engineering dilemmas. Nonetheless, discernment is paramount when deciding to integrate forged carbon fiber, considering both its advantages and environmental ramifications.

While the temptation to employ forged carbon fiber across a broad spectrum of applications may be alluring, it's imperative to acknowledge the substantial environmental footprint associated with its production. The energy-intensive manufacturing process and challenges in recycling post-use underscore the necessity of judiciously selecting when and where to utilize this material.

In the domain of prototyping, where innovation and efficiency reign supreme, forged carbon fiber offers distinct advantages. Its exceptional strength-to-weight ratio and design flexibility make it an optimal choice for crafting prototypes necessitating endurance during rigorous testing while maintaining lightweight and durability. By harnessing the unique properties of forged carbon fiber in prototyping, engineers and designers can expedite the development process, curtail iteration cycles, and ultimately expedite products to market more efficiently.

Moreover, in addressing specific engineering predicaments, forged carbon fiber shines as a solution for applications where traditional materials fall short. Whether devising components for high-performance vehicles necessitating lightweight yet sturdy construction or designing intricate structures requiring both resilience and precision, forged carbon fiber presents a compelling resolution. By strategically employing forged carbon fiber to surmount these unique challenges, engineers can unlock novel possibilities and expand the frontiers of what's feasible in their respective domains.

However, exercising prudence and restraint in the use of forged carbon fiber is paramount, particularly when exploring prototypes or addressing niche engineering dilemmas. While the material's attributes may offer unparalleled advantages in certain contexts, it's essential to weigh these benefits against the environmental consequences of its production and disposal.

In essence, while forged carbon fiber holds immense potential for prototyping and tackling specific engineering challenges, its judicious use necessitates deliberate consideration and prioritization of applications where its properties are genuinely indispensable. Employing forged carbon fiber for mundane consumer goods that do not derive tangible benefits from the material, or purely for aesthetic reasons, is not only frivolous but also environmentally irresponsible. By leveraging forged carbon fiber strategically and conscientiously, engineers and designers can drive innovation, surmount obstacles, and propel industries forward into a more sustainable future.

When to use

Part strength

Forged carbon fiber stands out for its exceptional strength properties, often comparable to that of aluminum. However, it's imperative to carefully assess whether this level of strength is necessary for the intended application. Before opting for forged carbon fiber, it's essential to ask pertinent questions such as, "Does this part truly require the strength of aluminum?" or "Could alternative materials like carbon fiber-reinforced PLA or Nylon suffice for prototyping this component?"

When evaluating the appropriate production method, it's crucial to consider the hierarchy of production levels. For instance, in my experience with rapid prototyping as a student, I prioritize different techniques based on the required strength and fidelity of the prototype. Beginning with FDM printing, which offers a balance between cost-effectiveness and speed, followed by SLA printing for finer details and increased accuracy. Next in line is SLS for superior strength and durability, and finally, composites like forged carbon fiber for applications demanding the highest levels of strength and performance.

It's important to note that while forged carbon fiber excels in strength, it may not be the optimal choice for all applications, particularly those with lower strength requirements. For prototypes where isotropy is the primary consideration, such as testing overall shape and fit, SLA printing may offer a more practical and cost-effective solution. Similarly, for verifying basic geometries and conducting initial assessments, FDM printing provides a rapid and accessible option.

In summary, while forged carbon fiber is renowned for its strength properties, its use should be carefully considered based on the specific requirements of the application. By strategically evaluating the strength needs of prototypes and considering alternative production methods, engineers and designers can optimize both performance and cost-effectiveness in their prototyping processes.

Example pieces

These part were made with forged carbon to not only save on material and tooling costs, but also as exploration parts to learn how forged carbon behaves and to gain experience in mold design.

Cons

Safety concerns

Forging carbon fiber is a process that demands stringent safety measures to protect your health. The method involves handling and manipulating materials that can release harmful particles and fibers into the air. Epoxy, used in the process, can become extremely hot when exposed to light and poses a risk of burns. Prolonged contact with epoxy can also lead to skin irritation and potentially cause allergic reactions.

During sanding, the risk increases as more particles are released, some of which are carcinogenic. To mitigate this, always wear an FFP2 mask and perform sanding in a well-ventilated area. Where possible, opt for wet sanding techniques, which help in reducing airborne particles significantly.

It's important to handle these materials with care and ensure that they are stored properly, away from children and animals. The workspace should also be regularly cleaned and secured to prevent accidental exposure.

Regular safety reminders will be provided throughout this guide. However, the responsibility to maintain a safe working environment rests with each individual. Always prioritize safety by using appropriate protective gear and following best practices for handling materials used in forging carbon fiber.

Less wear-resistant

While carbon fiber composites are renowned for their strength and lightness, they generally exhibit lower wear resistance compared to other materials like metals. This trait can limit their applicability in scenarios where surfaces are subject to frequent contact or abrasion. Over time, the wear and tear on carbon fiber composites can lead to degradation of the material's surface, potentially compromising its structural integrity and aesthetic appearance. This characteristic needs to be considered when choosing carbon fiber for parts that require high durability against physical wear.

Lower thermal resistance

Carbon fiber composites, while versatile and strong, have a lower thermal resistance compared to many metals, such as steel. This characteristic makes them less ideal for applications that involve prolonged exposure to high temperatures. The thermal stability of carbon fiber composites is generally limited by the type of resin used in the matrix, which can degrade or weaken at elevated temperatures. This is a crucial consideration in industries like automotive or aerospace, where components often face extreme thermal environments. Understanding these limitations is essential for ensuring the longevity and performance of parts made from carbon fiber composites in heat-intensive applications.

Environmental

Composites and materials contaminated with epoxy present significant environmental challenges as they are not recyclable. Proper disposal is essential to mitigate the potential environmental harm. This highlights the importance of responsible application of composite technology, emphasizing its use only in products or prototypes that genuinely benefit from its unique properties. Excessive or unnecessary use of composites not only leads to wastage of resources but also contributes to environmental pollution due to the complex disposal required. Stakeholders must prioritize sustainability by evaluating the necessity and long-term impact of using composites in their projects.

Pros

Strength-to-weight

When estimating the strength or rough dimensions of your part, you can use dimensions similar to basic aluminium. However, the part will be 30-40% lighter in weight.

Thermal expansion rate

Carbon composites are highly thermally stable, exhibiting minimal expansion when heated. This makes them perfect for applications like the build plate of a 3D printer.

Chemical resistance

The chemical resistance of the composite depends on the matrix material used. Epoxy is what I use and it is generally very resistant to chemicals.

High-temperature tolerance

Depending on the matrix, forged carbon can withstand **250-350°C** without losing strength. Aluminium generally starts losing strength from 200°C.

Very easy to process

Forged carbon is a relatively soft material, making it easy to work with using subtractive techniques. It allows for the inclusion of inserts or bearings without significantly compromising the material's integrity.

Isotropic material

Forged carbon requires less consideration for fiber orientation due to its isotropic nature, making it more resistant to damage like cut fibers. However, it's important to note that it is not stronger than carbon fiber weaves.

Design freedom

This material enables the achievement of shapes that would be challenging with carbon fiber weaves or subtractive methods.

Lower material costs

Forged carbon offers cost advantages for creating deep parts that would typically require the removal of significant material in subtractive manufacturing.

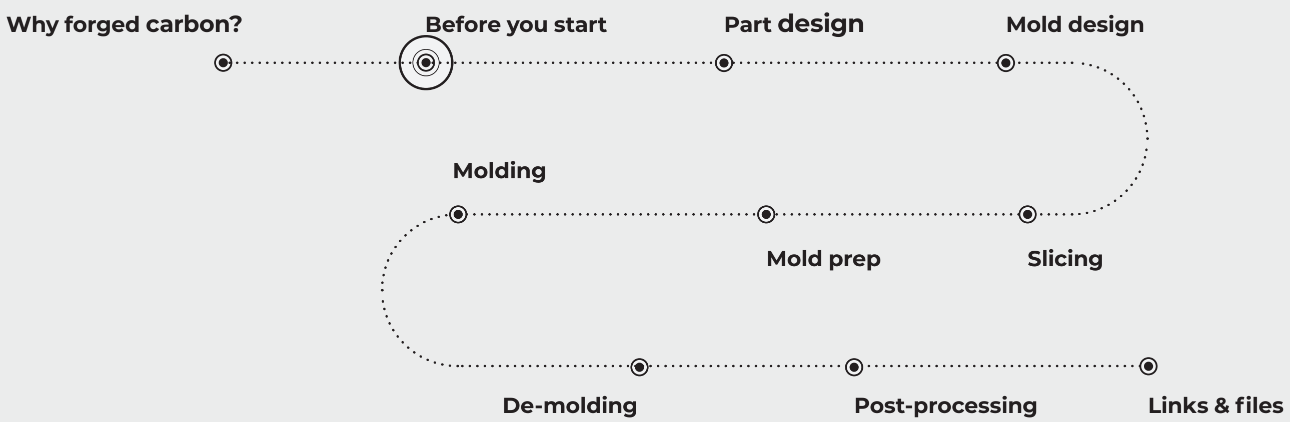
Tooling costs

You generally need less expensive tooling to make forged carbon pieces.

Fiber reinforcements

Strategically placing continuous carbon fiber strands along critical areas can make you part multiple times stronger. This can come in handy if you just want to quickly prototype a concept and not consider strength yet.

Stage 02
Before you start



Checklists

Before you dive into your project, I want to make sure you're fully equipped and ready to go. That's why I've put together a checklist of all the essentials you'll need, from safety gear to the right kind of workspace setup. This list is designed to help you prepare everything in advance, so you can focus on the creative part without any hitches. It's all about making your experience smoother and safer. Take a moment to review this checklist to ensure you've got everything covered and set yourself up for a successful and safe project. Feel free to put a check mark in the boxes to highlight the gear you already acquired.

A relevant checklist will also be included before every stage.

Safety gear

- [ ] **Safety glasses**
  Resin, fibers and cured fibers can fly into your eyes when filling or opening molds.

- [ ] **Respirator or FFP2 mask**
  Resin can emit volatile organic compounds, fibers can get airborne and enter your airways and during sanding or post-processing a lot of dangerous particles can get airborne if you do not wet sand.

- [ ] **Nitril gloves**
  During the molding stage and while handling a non post-processed part, you'll need to wear either Nitril, vinyl or latex gloves, ranked from ideal to good enough. Repeated contact with epoxy can cause skin irritation and can cause you to become allergic to the substance. Carbon fiber also easily enter the skin, causing irritation.

- [ ] **Working gloves**
  Tough work gloves that can resist sharp fibers will be needed to remove parts from the mold and to do post-processing on the part.

- [ ] **Protective clothing**
  Most of your skin should be protected to avoid fibers and epoxy coming into contact with it. So wear long sleeved shirts and long pants, or a lab coat. Also make sure this clothing can be permanently damaged.

- [ ] **Dirty footwear**
  Wear shoes that are allowed to get permanently dirty, as epoxy can drip on them.

Working environment

To protect you and other people, the right working environment is needed.

- **Children and animals**
  Your working area should be locked away from children and animals, as you will be working with dangerous substances.

- **Ventilation**
  Your working environment should be properly ventilated, as epoxy can emit volatile organic compounds (voc's), and carbon fibers are light enough to get airborne and pose a danger to your and other people's health.

- **Cleanliness**
  Ideally your working environment should be clean and dust free, as technically, particles that enter your composite can weaken the material.

- **Working area protection**
  You'll need a protected workbench and floor with either plastic or cardboard.

- **Chemical storage**
  Your chemicals and dangerous materials should be properly stored and locked.

- **Waste bin**
  Have a proper waste bin for epoxy contaminated materials and gear. Do keep in mind that you are not allowed to dispose of uncured materials in normal waste.

- **Fire safety**
  Have a fire extinguisher nearby, epoxy can overheat and start a fire.

- **Direct sunlight**
  Your working environment should not be exposed to direct sunlight, as added heat to epoxy will hasten the hardening process and cause the material to generate a lot of heat, melting or igniting its container.

- **Workbench**
  You should have a sturdy workbench with enough space to be able to work organized and safely.

- **Timer or clock**
  Have a timer or clock nearby, as your resin has a pot life, depending on the ratio of FAST and SLOW hardener, you may need to be fast.

- **Thermometer**
  A thermometer is critical as the temperature should at least be 18°C, otherwise your epoxy will get viscous and will not harden.

Mold fabrication tools and materials

Molds can be fabricated in a lot of ways, this guide focusses on 3D printing, but you can also use other techniques.

- **3D printer**
  There 2 main options to fabricate molds with 3D printing:

  FDM printer: these can be very inconsistent with their output if you have a lower end printer, and the parts it produces will need a lot of post-processing. However, materials are cheaper.

  SLA printer: these produce way smoother parts that require a lot less post-processing, however, the setup can be quite expensive compared to a cheap FDM printer.

  An important choice has to be made between a higher cost for your setup or more post-processing. This will be talked about further in a coming chapter.

- **Printing material**
  PLA, PETG and reinforced filaments for FDM printing.
  ABS like resins for SLA printing, tough and easy to print and post-process.

- **Spray putty**
  Spray putty will have to be applied before and after sanding.

- **Sanding paper**
  Sanding paper ranging from 60 to 2000, your mold surface will have to be smooth, otherwise your parts will stick to the mold surface.

- **Nuts and bolts**
  Having a range of bolts and nuts will allow you a lot of flexibility to design your mold.

Molding materials

Materials like fibers and epoxy

Chopped fibers 12mm
There are 2 main choices, chopped carbon fiber, or chopped basalt fibers. I like to use basalt to prototype parts that do not need as high of a strength-to-weight ratio compared to carbon fiber, as this is more environmentally responsible.
12mm Chopped fibers are also a balanced choice, enabling you to make small and big parts. These fibers can still be cut smaller to maybe fill thin features.

Continuous carbon fiber tow
Depending on the part, continuous fibers can be added to the chopped fibers, greatly increasing the part's strength. Increasing the strength-to-weight of the part.

IN2 infusion epoxy + AT30 FAST hardener
Infusion epoxy should be used, this will be critical as excess epoxy as to be able to flow out of the mold. Do be sure to roughly calculate the amount you will need before you start your project.

AT30 FAST and AT30 SLOW hardener
I recommend using a 1/3 FAST and 2/3 SLOW hardener to lengthen the pot life of the epoxy, giving you more time to mold your part, while keeping hardening times within a day.

PVA or similar release chemicals
Your mold surface will have to be coated with a release agent, there are a lot of options, but you should use high quality materials, as opening and re-using the mold will get very hard.

Filleting wax
Filleting wax is used to cover threads or other features where epoxy should not flow but could flow.

Epoxy coating resin
An epoxy specific for coating a carbon fiber part.

Clear coat spray paint
Can act as a clear coat, increasing surface finish and add contrast to the fibers

Consumables

All the consumables you'll need to fill the mold and post-process your part

Paper cups
You'll need a lot of paper cups to mix your epoxy and weigh your fibers, they'll need to be at least 200ml.

Mixing sticks
Mixing sticks are used to mix your epoxy, these should be sturdy and not flake. Ice cream sticks are a cheap option and will serve their purpose. These can also be used to push down fibers.

Flat bristles
These can be small and cheap nylon bristles, but the most important feature is that they do not lose any hair. These will contaminate your material.

Working area protection
You'll need a protected workbench and floor with either plastic or cardboard.

Paper towels
You will need a lot of paper towels to clean your work area, mold or hands. Always keep these nearby.

PET tape
Used for covering split lines and even mold surfaces.

Tools

Hardware you need to open and close your mold.

Soft hammer
You may need to "persuade" the mold or part to release by giving it a tap with a soft hammer.

Prying tool
A tool that fits between the mold split lines and is sturdy enough to receive some light taps from a hammer and be used to pry open the mold.

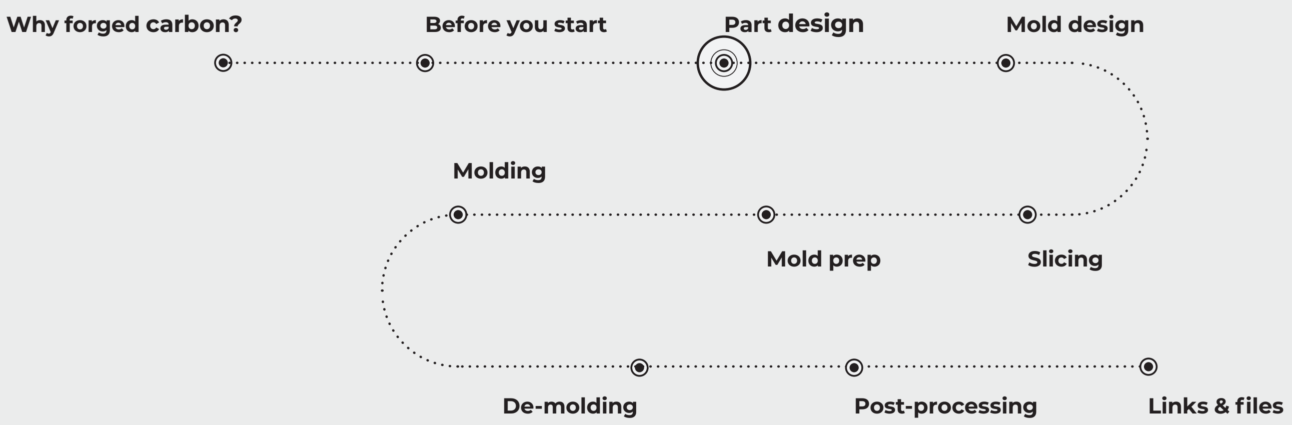
3D printed bottle drip caps
3D printed bottle caps that help you slowly drip your epoxy and hardener out of their container, ensuring you get an accurate measurement.

Soft de-molding wedge
A soft piece of plastic that you can either buy or 3D print, this helps you to open a mold or remove a part from the mold without damaging the mold itself.

Table clamps
Clamps to either close your mold or keep your mold closed, these should be very sturdy as they can bend if they aren't stiff enough.

Closing rig
A rig you make yourself or a vise that you can use to close your mold, you will have to put down a lot of force.

Stage 03
Part design



Important rules

Design for forged

When designing your part, it's crucial to remember that it will be made in forged carbon. Keeping this in mind from the start helps streamline the mold-making process later on. By designing specifically for forged carbon, you avoid the need to switch back and forth making adjustments. This approach not only saves time but also ensures that your design is optimized for the material's unique properties, resulting in a smoother workflow and a better final product.

Adapt to your needs

In this guide, I'll showcase examples from earlier projects, demonstrating how to tailor forged carbon techniques to your specific needs. These examples will highlight possibilities and should encourage creative adaptations.

Drafts

Draft angles are crucial in the molding process of composite materials, including forged carbon. These angles facilitate the removal of a part from its mold without causing damage to either the part or the mold. For forged carbon pieces, incorporating a sufficient draft angle is essential, especially when dealing with intricate designs or deep molds. Generally, a minimum draft angle of 1 to 3 degrees is recommended, though this can vary based on the complexity of the part and the specific molding technique used. Proper draft angles ensure the longevity of the mold, improve the quality of the finished parts, and reduce manufacturing defects.

No limits

There are almost no limits to your part when using 3D printing for mold production. You can split your mold into multiple pieces to handle complex shapes traditional methods can't. Plus, materials like PVA allow you to dissolve parts of your mold afterward, enabling intricate features and internal structures that would otherwise be impossible. This makes 3D printing incredibly versatile for innovative designs.

Dimensional accuracy

Dimensional accuracy in forged carbon pieces really depends on how precise your mold is because the final part will directly mirror the mold. If you're using FDM printing to create your molds, remember to slightly overdimension them to account for any material shrinkage or crimp. This small adjustment can make a big difference in ensuring your final product meets your expectations for quality and detail.

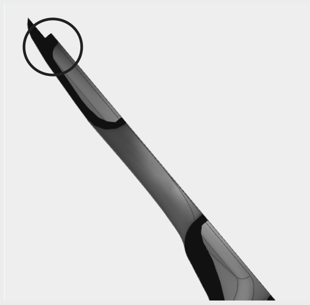
Part design

Undercuts

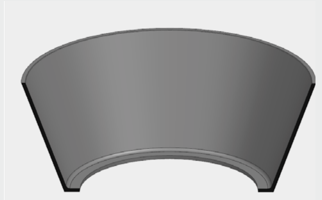
The number of undercuts and their orientation in your design is a key factor in determining how many parts your mold should consist of. Always aim to minimize or avoid undercuts whenever possible, as even small undercuts can prevent the successful release of your part from the mold. Keeping this in mind will help streamline your mold-making process and enhance the manufacturability of your design.

Avoid deep thin walls

When designing thin-walled features that protrude, it's essential to pre-fill these areas to improve the distribution of fibers, though achieving the ideal fiber ratio remains challenging. The pre-filling process is critical as it helps position the fibers closer to their final locations before molding begins. Despite pre-filling, these features typically do not reach optimal strength due to limitations in fiber compaction and orientation.

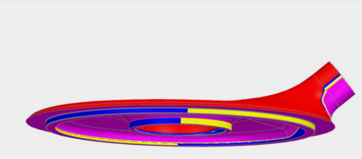


However, consistent wall thickness across the part, like the example shown on the right, allows for more uniform fiber placement. In such designs, you can apply a consistent layer of fiber material to ensure even wall thickness. Fibers will redistribute themselves somewhat and should achieve optimal fiber content.

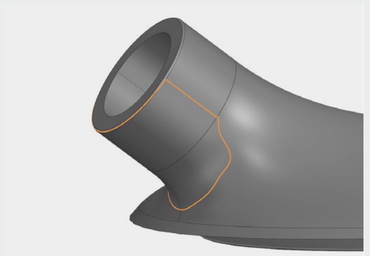


Draft analysis

Depending on the software you're using, you can utilize a feature known as "draft analysis," typically employed in injection molding, to check for any undercuts in your part that you might have missed. This tool allows you to set the orientation of the ejection direction, highlighting any undercuts present.



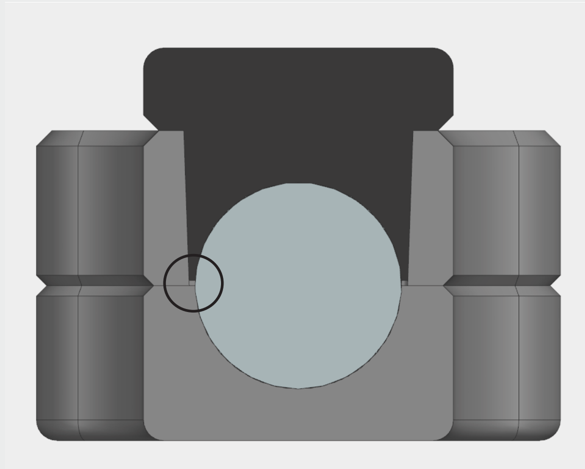
Draft analysis can also be useful for determining the split line of your part or mold. Some programs not only visually indicate where this line should be but also allow you to select it, making it possible to use this split line for further geometric operations. This feature is incredibly helpful for planning how your mold will come apart and ensuring easy ejection without damaging the part.



Part design

Edge blends on top surface or split line

A common mistake in part design is adding an edge blend or thin wall on a top surface, which can weaken your mold or may be unprintable. This issue often occurs on the male side of the mold. For example, on the right, you can see an issue with a circular feature where the male side tapers to a 0 mm width, which cannot be printed. To prevent this, you should either model in a small flange with a minimum width of 0.8-1.2 mm and 0.5mm thickness, or redesign your part to maintain a thicker wall. These adjustments ensure the mold's integrity and printability.



Holes

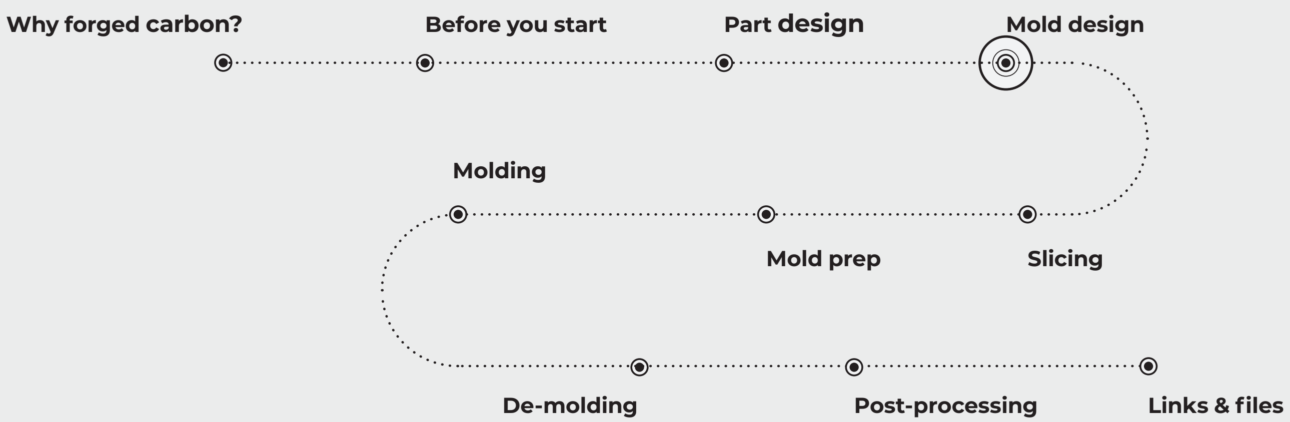
You can incorporate holes into your design, but it's crucial to draft them appropriately to ensure you can remove your part from the mold easily. For deeper holes, I recommend using separate inserts that are bolted to the mold, as these can break more easily and will wear down quicker. Additionally, the orientation of these holes is critical; they must align with the mold's opening direction. If they do not, you will need to create them using mold inserts or separate prints. This careful planning helps avoid complications during the molding and demolding processes, ensuring a smoother manufacturing workflow.

Threads

Modelling threads directly into your forged carbon part is generally not advisable. While it is possible to cut threads into a forged component, doing so can compromise the material's consistency and strength due to the nature of fiber materials. Additionally, threads in such materials tend to wear out more quickly. These threads will perform about as well as threads cut in teflon.

Instead of cutting threads, consider using inserts. Inserts molded directly into the part during the manufacturing process can enhance strength but may complicate mold design. Alternatively, inserts can be added after the part is formed; this method requires precise dimensions and may involve using epoxy glue or a pressure fit to secure the inserts. Both methods help maintain the integrity of the material while providing the necessary thread functionality.

Stage 04
Mold design



Important rules

Compression area

The fibers and epoxy need to be compressed, that is why a compression volume/ depth is needed. For an idea of how deep this has to be, you can use a formula I have devised. This formula is a great indicator of how deep this feature has to be. and if your mold maybe has to be redesigned.

Divide in pieces

Do not be afraid of dividing your mold into multiple parts. This actually reduces the amount of post processing you will have to do. A 2 piece mold for example will need very smooth surfaces to allow part extraction or even opening of the mold.

Undercuts

Be mindful of undercuts, it will be critical to design your mold in a way that doesn't interfere with the ejection of the part.

Combine manufacturing techniques

I like to combine manufacturing techniques to reduce the cost, post-processing time or complexity of the mold. If you have high detail part that you want to come out of your mold in a pristine state, I would use SLA printing to print the cavities, FDM for the distribution plate on top and bottom, reducing material use and cost. The top slab also gets damaged more easily, so instead of having to replace everything, you may be able to replace parts of your mold.

Mold design

2 Piece mold

A basic mold consists out of 2 big parts: the female side and the male side. The female can most of the times be identified as the side with the main cavity. The male side on the other hand can be identified by the part that has to slide into the cavity.

These mold are easier to design and manufacture, however, they do pose challenges. As parts can be hard to extract, everything needs to be drafted to be able to release and post-processing a cavity can be challenging and time consuming.

This is why I do not reccomend using a classic 2 piece design, I have tested this a multitude of times and have experience a great amount of failed molds, mostly due to the mold surface not being post-processed to perfection or printing artifacts.

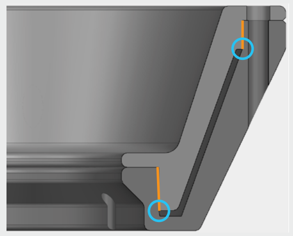
The 2 piece mold does have a place, it can be used for an ultra fast prototype that does not require you to extract the part. Or for parts that have a big draft and will naturally release from a mold surface, even if it hasn't been post-processed.

Female side

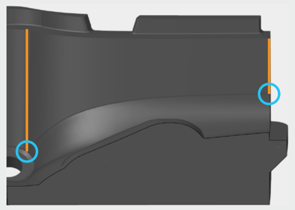
The cavity

The cavity is the main section where your part takes shape. It should be designed with precise dimensions and drafted edges to facilitate easier part removal. A proper draft angle is essential here; without it, the part can become stuck, leading to a challenging extraction process. Given that post-processing can be difficult and time-consuming, ensuring a smooth cavity surface is crucial, either through careful 3D printing or post-processing techniques.

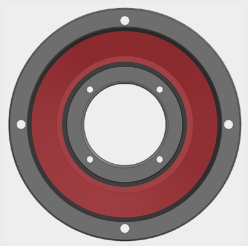
The Compression Area (Raised Edge)



The raised edge serves as a buffer zone for the fibers, allowing them to be evenly distributed before the compression process begins. The height of the raised edge is crucial, it must be sufficient to contain the fibers and resin during compression.



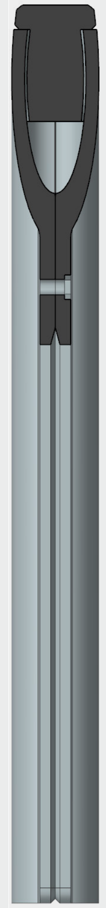
As a rule, the **raised edge height** can be seen as the highest point of the female mold cavity to the top . Meaning in a not very flat mold like the one on the right, the height should be added from the center of the **highlighted circles**. And in case there is a hole in the part, you can either even out the edge at the top of the part, or in a thin walled part you can also just duplicate the raised edge, even on sloped parts like the image on the right. Although, having a flat mold top is recommended to reduce flex.



To calculate the optimal height for this raised edge,use this a simple formula that considers the volume of the part and the **projected surface area of the mold cavity**. On the right you can see the top view of a mold. Using this formula helps to determine the minimum height required for the compression area, providing a more consistent outcome during the molding process.

Mold design

$$Raised\ edge\ height = 5mm + \frac{Part\ Volume(mm^3)}{Top\ surface\ area(mm^2)}$$

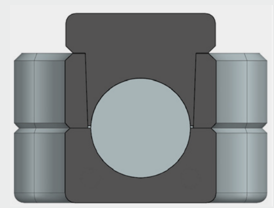


When using the derived formula to calculate the ideal height for the raised edge in your mold, always round off your results to one decimal point. This approach provides a useful **indicator of whether your mold design is adequate.** For instance, a result exceeding 125mm could suggest that your compression area is too small, leading to issues with proper fiber compression and distribution throughout the mold.

Here's an **example** that illustrates the importance of this calculation:
I designed a cylinder with a diameter of 20mm and a length of 250mm. To fill this cylinder, I created two different molds—one designed to compress fibers from the top and another from the side.

The top-filled mold presented significant challenges. I struggled to compress all the fibers, which made closing the mold difficult. Additionally, when examining the processed part, I found that the fibers at the bottom weren't optimally compressed.

The side-filled mold, on the other hand, featured a 10mm raised edge, which I found to be adequate but difficult. This part forged perfectly, leading to consistent compression throughout the process. From this experience, I derived the formula for calculating the raised edge height. Plugging the side-filled mold's parameters into the formula yielded 15.7mm, while the top-filled mold's values resulted in 250mm. This significant difference indicated that the top-fill mold's design was flawed due to inadequate compression.

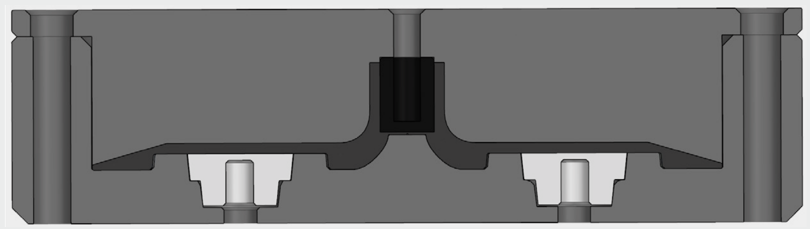


Based on this information, if I were to redesign the top-fill mold, I'd add a piston to both sides, effectively doubling the compression area. This modification would provide enough buffer space for the fibers while allowing for compression from both sides, resulting in a more evenly compressed and stronger final product.

This example demonstrates that using the formula and interpreting the outcomes correctly can help you identify potential issues in your mold design, leading to more successful results in projects.

Part extraction features

Parts in a 2 piece mold or cavities that can't be split can be extracted via "dow pins" or extraction features, these are cylinders or features that are mounted onto the female side of the mold before it is filled. They can be an insert that may be needed to define a part feature like a deep cavity(black part below), or a part that sits flat with the part surface . A good rule is to always draft on both sides of this part and **tension it against the mounting side of the mold**. Otherwise epoxy flow through the mounting point's gaps and glue it to the mold.
When the part is cured you remove the bold tensioning it against the mold and use a longer thinner bolt or cylinder to knock the part out of the mold cavity.



Mold design

Feature inserts

The black PLA part above was used to form a perfectly dimensioned hole and extracted by melting it out. Holes that aren't cut out of the material will be stronger as fibers will run around this part. Yet, the strength of this feature can be compromised. This because it is harder to fill the thin walls with the relatively big fibers, with the added possibility of fibers not correctly being compressed in this cavity.

Normally, insert have to be tapered, but the black insert in the image above needed to be straight, as a bearing had to be mounted in this hole. Yet, by using a PLA insert, you are able to melt the part and pull it out. The dimensions transfer perfectly allowing you to for example mount a bearing.

PVA is also a material that can allow you to add features that would normally not be able to release, by being able to be dissolved. However, do be mindful that you will need to correctly store this material as it can absorb water from the air and become difficult to print.

Threads

Directly cutting threads into your part is not recommended, as when you cut threads, you cut the fibers that give your part its strength. While you can do it for non critical connections or quick prototypes, repeated operations will wear out the thread and weaken it further.

If you do decide to do this, I recommend reinforcing the area where you are going to cut the thread with fiber you cut as small as possible, this will result in a much stronger thread. This has been checked in my thesis.

When you want to add threads to your part, it is recommended to use inserts. While there are composite specific inserts, you do not need to use these. There are a wide variety of brass inserts for the 3D print market, when used correctly, these will suffice for most applications, it is even possible to add your own machined or printed insert.

To use these brass inserts you will have to tension them to the inside of the mold like the ejection feature mentioned above. But, you will have to use filleting wax to protect the thread, otherwise epoxy may enter the threads, this normally will not prevent you from getting the bolt out , but it will make the thread contaminated and more difficult to use. Epoxy may also leak from unintended places.

If you do not want to buy filleting wax or run out, you can first tension the insert against the mold surface, and then seal the hole with hot glue.
Or buy inserts with a closed end.

Mold design

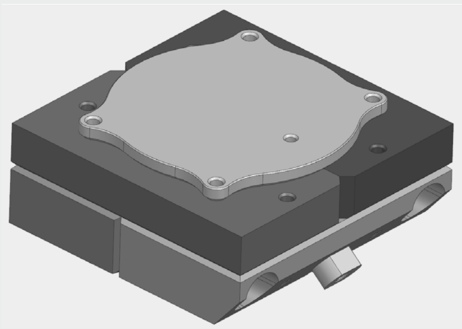
Multi-part molds

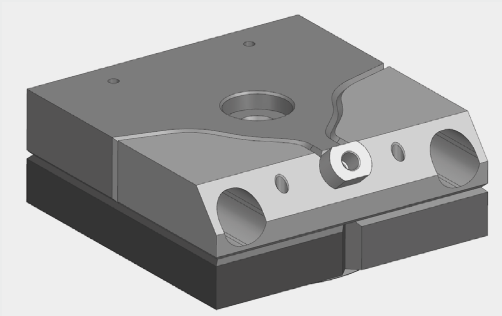
Multi-part molds are a flexible choice for creating complex parts with forged carbon fiber. If designed properly, they can reduce the need for extensive post-processing, streamlining the production process. They also offer a straight compression area, reducing the chances of fibers getting stuck, making mold closure easier.

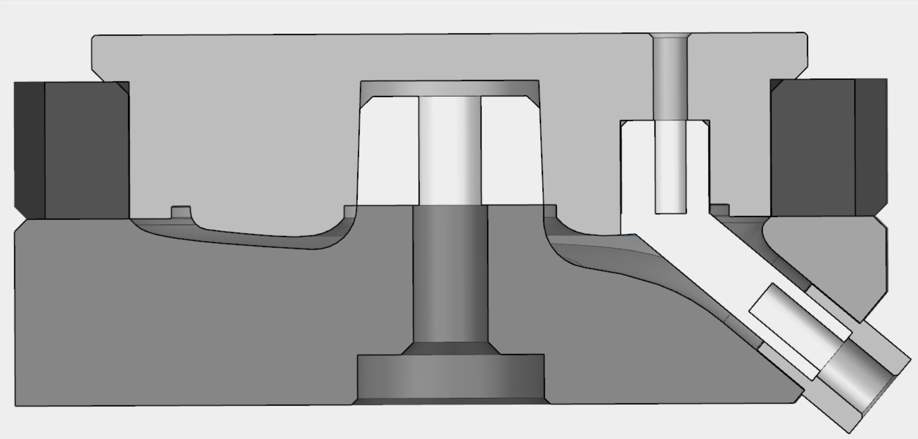
For those using FDM printing, multi-part molds can be a game-changer. Post-processing a large, single-piece mold can be time-consuming, sometimes taking up to a full day. Multi-part molds, however, allow for easier sanding, cleaning, and assembly, speeding up the overall workflow. Plus, you might not need extra extraction features since the segmented design makes de-molding easier.

However, there's a caveat: FDM printers aren't known for producing the most dimensionally accurate parts. This means that even small inaccuracies can stack, so a part that's 0.2 mm off could end up 0.4 mm off, depending on how many parts are involved. These tolerances vary from printer to printer, so it's crucial to check for accuracy once the part has been de-molded. Despite this limitation, multi-part molds still offer a practical approach to creating functional parts with minimal post-processing. Their flexibility makes them a valuable option for anyone using FDM printing to produce high-quality forged carbon parts.

To sum up: dividing the lower cavity into parts can make part extraction easier, reduce post-processing, and lead to better fiber fill and compression.
Below you can find some examples.







Mold design

Multi-part mold design tips

Bolt sizes

Bolt sizes depend on their placement, the amount of bolts and the load they will experience. If possible use at least M5 bolts to connect parts. Bigger bolts never give worse results but may impact print times.

Modelling the holes, be sure to leave one half with no thread, and one with thread, visible in the image above,where the hole that the bolt enters is big enough to slide through it.

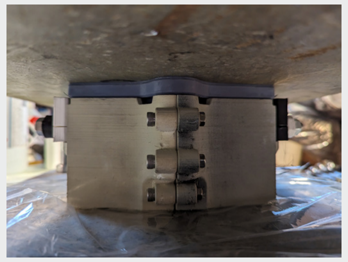
Bolts will either have to be threaded into your parts, or you can add a nut on the other side that tightens the 2 pieces.

I mostly thread straight into my printing material as I have a thread cut set, however, using nuts will lead to less post-processing time and a stronger connection.
Do remember that you also have to coat these with PVA.

Flat mold top and bottom

It is always a best practice to have a flat top and bottom on your mold.

So make sure to add cavities for your bolt head when they are placed on the top or bottom of the mold with enough extra space for your relevant tightening tool. This why I recommend using M5 bolts where possible, as they are most of the time tightened using a hex key and thus do not require extra room.



Multi-material/printing technique

Molds can be a combination of multiple printing techniques.
For example, I like to print my male mold side with an SLA printer, and the female side with an FDM printer. This lowers the material costs, as resin costs more than PLA or PETG. The male side is a lot of the time the smaller part. This will also lower the post-processing time and normally prevent the male side of needing ejection pins, as your surface will already be smoother than the female side.

Mold design

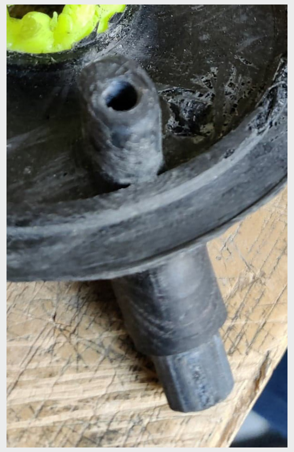
Meltable, one time inserts

There are creative ways of using inserts that allow you to achieve very special cavities.

Insert can be made with the intention to be destructively removed after the molding. Depending on the material or technique you use, this will differ.

PLA inserts can be molten out of your mold by simply using a lighter and some pliers. Do be mindful that heated and then cooled PLA will anneal and become much stronger.
If the insert allows for it, you could of course also just drill it out with a drill that is 1 mm smaller than the final diameter.

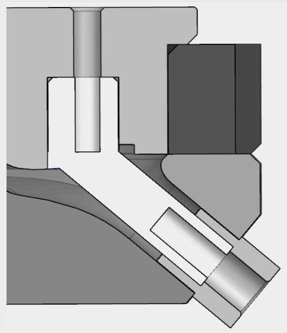
PVA is also a valid option for inserts, as you can simply dissolve them, not risking any damage to your mold.



Double compression area

Some areas may be harder to correctly pre-fill, as they are harder to reach or are too thin. This could result in less than optimal part strength. To counter this you can incorporate a double compression area.

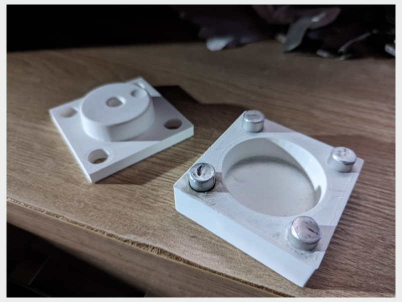
This part for example had a thin walled section in a n awkward place in the mold. Thus I incorporated an extra piston, this would allow me to place fibers deeper into the mold before compression. making sure the amount of fiber to reach the optimal ratio are there.
First compressing the top of the mold, and securing the insert.
Then, tightening the smaller piston, this to ensure I was compressing the fibers and not just pushing them away.



Alignment pins

Sometimes, parts are round but need some internal features to be in a certain orientation or placement. Too ensure good orientation of the mold, alignment pins or features can be used.

There are 2 main choices for this:
Cylinders/ bolts that go trough holes or features in the male side of the mold.
Or features on the surface of the mold, these can be cones or dents, do remember that these can impede mold separation if they can't be removed, thus a sideways opening mold may not be able to be opened if the male side hasn't been lifted or removed yet.



Mold design

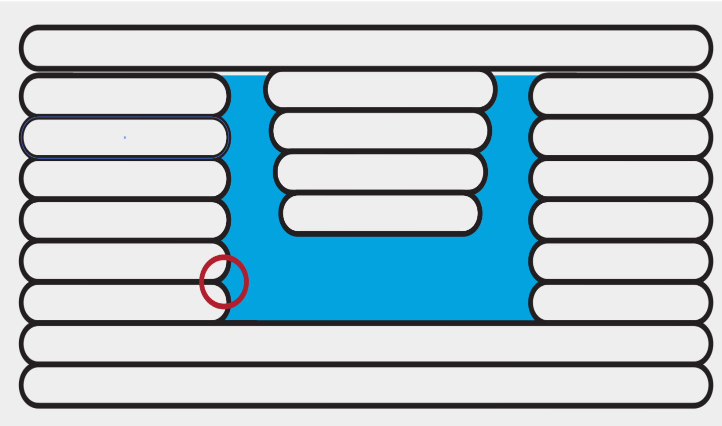
A different approach

Design to lower post-processing times of mold

The approach I like most is to design your mold in such a way, that mold parts do not need as much post-processing pre molding. This also decreases print times, I for example print at 0.28 mm, give the mold a rough sanding with an 80 and 400 grid, then a fast pass with 800 and nothing else.

Design around layer lines

Assume you will have big layer lines, a mold can not open if the opening direction is anything else than the layer line direction. The epoxy will grip into the mold as you can see in the image below.



Flexible moulds

Design your mold with thin walls (1.2 mm- 2 mm) that are secured in a baseplate with screws. The screws wil give riggidity, while the thin walls will help when opening the mold by being able to flex.
Make sure that the compression area also allows this, or splits open.

Mold design

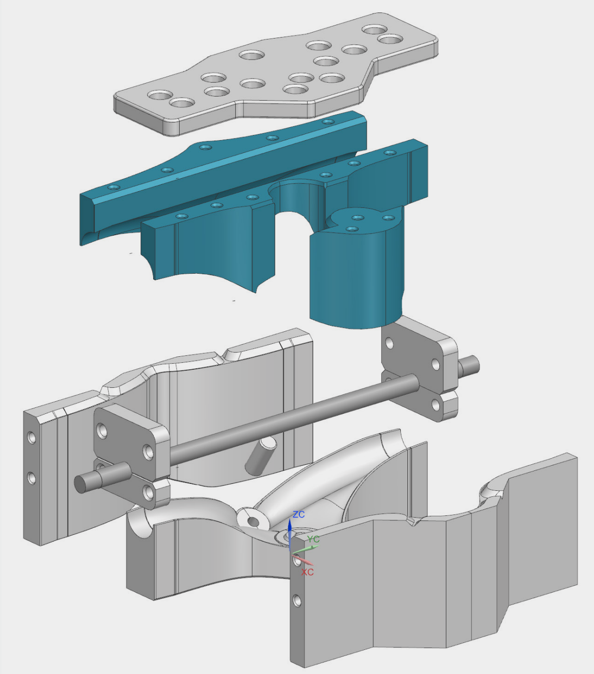
Split everything

A solution to this, is to split everything that would grip a part along 2 sides.

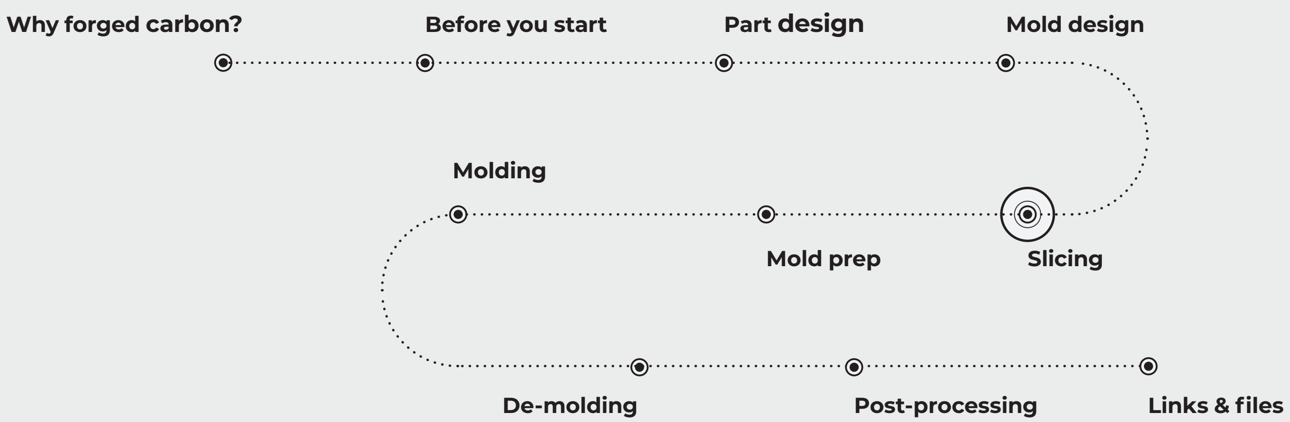
Here you can see the mold design for a forged carbon skateboard truck. This mold employs this idea. It keeps the walls of the compression area straight, allowing for easier mold closing ,and prevents fibers from getting trapped when compression is happening. Everything is split and the center female side of the mold can flex, allowing for the extraction of the part.

However, the splitlines you create will fill with epoxy, so either design the parts with a channel that gets rid of the epoxy.

Or, apply **PET tape (clear tape)** to the splitlines if possible. PET tape easily releases from epoxy. Do try to work with long strips of tape, and not too many small strips , these can let epoxy flow through and are harder to remove.
You can find en example of this down below.



Stage 5
Slicing



Important rules FDM printing

Wall thickness

To withstand the pressure of the molding process, walls should have a minimum thickness of at least 2.4 mm, I even recommend 3 mm wall thickness

Top/bottom thickness

The thickness of your horizontal surfaces, this setting may increase printing times significantly but is necessary to counter deformation of the mold. This should be at least 1.2mm

Layer height

Set as low as your nozzle and machine allow without losing print quality, try to balance this with the amount of time you have to fabricate your carbon part, the mold design and the amount of post-processing you want to do.

Infill

Infill should be at least 60%, I have found this is a good balance between material usage and mould toughness. Infill type depends on the amount time you have, cubic is strong enough for most molds, however gyroid is stronger but will take longer to print

Balance

The key is balancing printing time, desired results, and post-processing effort. For quick prototypes, design the mold to release parts easily, reducing the need for extensive mold post-processing. Carbon composites are easier to process than molds, so for single-piece runs, minimal mold work is ideal.

If you have access to an SLA printer and the budget to use it, this can greatly improve accuracy and surface finish. Choose the method that aligns with your project’s needs and the time you want to spend on post-processing.

Checklist

Working environment

- [ ] **Children and animals**
Your working area should be locked away from children and animals, as you will be working with dangerous substances.

- [ ] **Ventilation**
Your working environment should be properly ventilated, as epoxy can emit volatile organic compounds (voc's), and carbon fibers are light enough to get airborne and pose a danger to your and other people's health.

- [ ] **Cleanliness**
Ideally your working environment should be clean and dust free, as technically, particles that enter your composite can weaken the material.

Mold fabrication tools and materials

Molds can be fabricated in a lot of ways, this guide focusses on 3D printing, but you can also use other techniques.

- [ ] **3D printer**
There 2 main options to fabricate molds with 3D printing:

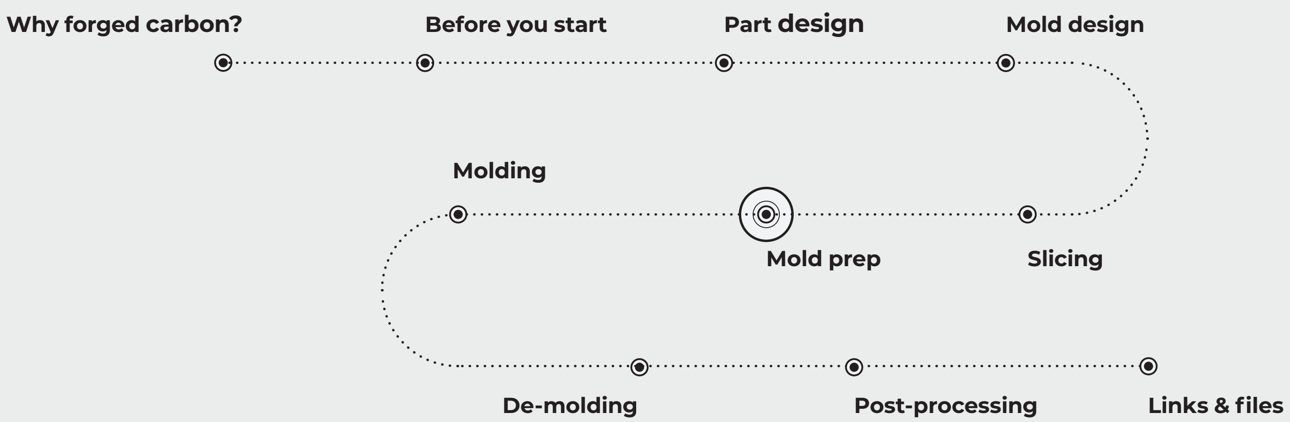
FDM printer: these can be very inconsistent with their output if you have a lower end printer, and the parts it produces will need a lot of post-processing. However, materials are cheaper.

SLA printer: these produce way smoother parts that require a lot less post-processing, however, the setup can be quite expensive compared to a cheap FDM printer.

An important choice has to be made between a higher cost for your setup or more post-processing. This will be talked about further in a coming chapter.

- [ ] **Printing material**
PLA, PETG and reinforced filaments for FDM printing.
ABS like resins for SLA printing, tough and easy to print and post-process.

Stage 06
Mold prep



Important rules

Minimal sanding

Not every mold requires the same amount of post-processing. But they should all at least be sanded down once. Depending on the layer height, your part could grip the mold at certain angles.

2 piece vs multi-part mold

A 2 piece mold will have to be sanded to perfection, otherwise your part will not release and you will have to destroy your mold. Sanding should at least end with a 1200 grid sanding paper, but going even higher will only benefit releasing qualities.

Well designed multi-part molds do not necessarily need post-processing. A good rule of thumb is that a surface does not need to be sanded if your mold opens parallel to your layers.

Effort vs needs

Balance the amount of time you want to invest vs what you need. You should always make it as easy as possible for yourself. Do not overpocess the mold. And if possible, just use SLA printing, it sands so much easier, prints way better, has no seams and is more accurate.

Checklist

Safety gear

- [ ] **Respirator or FFP2 mask**
Resin can emit volatile organic compounds, fibers can get airborne and enter your airways and during sanding or post-processing a lot of dangerous particles can get airborne if you do not wet sand.

- [ ] **Nitril gloves**
During the molding stage and while handling a non post-processed part, you'll need to wear either nitril, vinyl or latex gloves, ranked from ideal to good enough. Repeated contact with epoxy can cause skin irritation and can cause you to become allergic to the substance. Carbon fiber also easily enter the skin, causing irritation.

Working environment

- [ ] **Children and animals**
Your working area should be locked away from children and animals, as you will be working with dangerous substances.

- [ ] **Ventilation**
Your working environment should be properly ventilated, as epoxy can emit volatile organic compounds (voc's), and carbon fibers are light enough to get airborne and pose a danger to your and other people's health.

- [ ] **Chemical storage**
Your chemicals and dangerous materials should be properly stored and locked.

- [ ] **Waste bin**
Have a proper waste bin for epoxy contaminated materials and gear. Do keep in mind that you are not allowed to dispose of uncured materials in normal waste.

Checklist

Mold fabrication tools and materials

- [ ] **Spray putty**
Spray putty will have to be applied before and after sanding.

- [ ] **Sanding paper**
Sanding paper ranging from 60 to 2000, your mold surface will have to be smooth, otherwise your parts will stick to the mold surface.

- [ ] **Nuts and bolts**
Having a range of bolts and nuts will allow you a lot of flexibility to design your mold.

Mold prep

Post processing steps

Post-processing occurs in several steps, and some of these may need to be repeated. Below are the steps to post-process a mold part to perfection. You can stop in each step, you should determine this based on your specific needs, as this is only a general guideline.

1. Apply putty or filler

Apply a thin layer of spray putty or filler that fully covers the cavity of the mold, I like to use Motip spray putty/filler as it dries very well and is easy to sand. It is beneficial to initially use filler, this creates a nice contrasty base layer that helps you see holes or still to be sanded down areas later on.
Using a black filament also works wonders with this, as the filament will become white when sanded down
You can also alternate between layers of putty and filler for extra contrast, yet I do not do this as filler is quite a bit more expensive.

2. Sand with 120 grid

Let the putty dry for 30 minutes and then sand down the surface until you can see the layer lines again.
Use **wet sanding**, this not only achieves a better surface quality, it keeps particles from entering the air , it also cleans the sanding paper so it doesn't clog, making the sanding process easier and faster.

3. Apply putty

Apply a thin layer of putty again.

4. Sand with 180

Let the putty dry for 30 minutes and then sand down the surface until you can see the layer lines again.

5. Apply putty

Apply again

6. Sand with 320

Let the putty dry for 30 minutes, now start sanding the mold more carefully, try to not expose the layer lines. Slider your finger over the mold surface, it should start feeling smooth.

7. Apply putty

Apply again

8. Sand with 600

7. Apply putty

This should be the final layer of putty, make it really thin, this layer is only here to allow you to sand it with multiple higher

9. Sand with 800

10. Sand with 1200

11. Rinse parts

Rinse all your parts with water to prevent your carbon piece to be contaminated with putty

12. Optional glossy spray paint

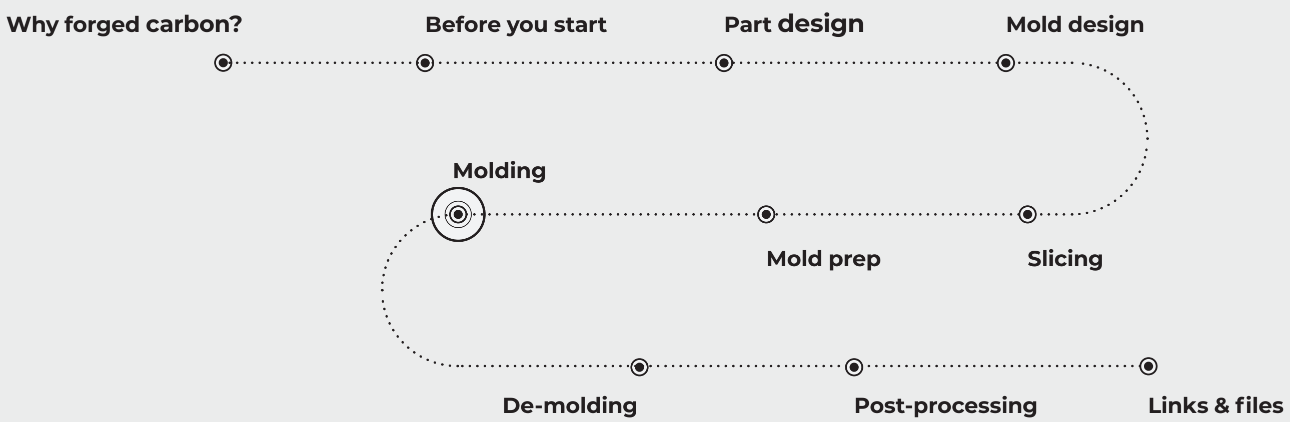
Applying a glossy spray coat as the final layer of your mold's surface treatment can be beneficial for achieving a smooth finish and enhancing the mold's durability. A glossy surface can make the mold more resistant to sticking, aiding in part release. Additionally, it can create a more visually appealing finish, which can be useful for ensuring consistent part production quality.

However, there are potential risks to consider when using a glossy spray coat as the final surface treatment:

Adhesion Issues:
If the spray coat doesn't bond well with the underlying surface, it could peel or flake off under pressure or pulling forces. This can lead to defects in your molded parts or cause the mold to deteriorate faster.

Chemical Compatibility:
Ensure the glossy spray coat is compatible with the materials used in your mold and the composite you're molding. Some paints or coatings may react with resins or release agents, causing unwanted effects like bubbling or tackiness.

Section 07
Molding



Important rules

Safety

It is really important to respect all the safety measures, double check the checklist. As frequent exposure can lead to long term problems.

Also, from this point on, **always** wear gloves, fibers easily enter the skin and epoxy is also very bad for you.

Properly prepare

You should be 100% sure that when you start the molding process you'll be able to finish it. Double check everything, mold parts, bolts, chemicals, safety gear, closing gear.

Allocate enough time

You should allocate at least 2-3 hours to prepare the space/materials, mold and clean everything. Having to hurry can result in making mistakes.

Working temperatures

Because of the safety concerns, you might be tempted to work in a shed or outside. But you should keep in mind that the minimum processing temperature of your epoxy is 18°C, any lower and the viscosity of the infusion resin will be too high and will impede mold closure and result in a failed part. The same goes for the curing of the part, curing only happens at above 18°C.

Time awareness

Be mindful of when you mixed your epoxy components, as this is very important. Your resin has a pot life that depends on the kind of hardener (SLOW or FAST).

Checklist

Safety gear

Probably the most important items you'll need is safety gear. Composites use materials that can be quite harmful if not handled properly and with care.

- [ ] **Safety glasses**
Resin, fibers and cured fibers can fly into your eyes when filling or opening molds.

- [ ] **Respirator or FFP2 mask**
Resin can emit volatile organic compounds, fibers can get airborne and enter your airways and during sanding or post-processing a lot of dangerous particles can get airborne if you do not wet sand.

- [ ] **Nitril gloves**
During the molding stage and while handling a non post-processed part, you'll need to wear either Nitril, vinyl or latex gloves, ranked from ideal to good enough. Repeated contact with epoxy can cause skin irritation and can cause you to become allergic to the substance. Carbon fiber also easily enter the skin, causing irritation.

- [ ] **Protective clothing**
Most of your skin should be protected to avoid fibers and epoxy coming into contact with it. So wear long sleeved shirts and long pants, or a lab coat. Also make sure this clothing can be permanently damaged.

- [ ] **Dirty footwear**
Wear shoes that are allowed to get permanently dirty, as epoxy can drip on them.

Checklist

Working environment

- [ ] **Children and animals**
Your working area should be locked away from children and animals, as you will be working with dangerous substances.

- [ ] **Ventilation**
Your working environment should be properly ventilated, as epoxy can emit volatile organic compounds (voc's), and carbon fibers are light enough to get airborne and pose a danger to your and other people's health.

- [ ] **Cleanliness**
Ideally your working environment should be clean and dust free, as technically, particles that enter your composite can weaken the material.

- [ ] **Working area protection**
You'll need a protected workbench and floor with either plastic or cardboard.

- [ ] **Chemical storage**
Your chemicals and dangerous materials should be properly stored and locked.

- [ ] **Waste bin**
Have a proper waste bin for epoxy contaminated materials and gear. Do keep in mind that you are not allowed to dispose of uncured materials in normal waste.

- [ ] **Fire safety**
Have a fire extinguisher nearby, epoxy can overheat and start a fire.

- [ ] **Direct sunlight**
Your working environment should not be exposed to direct sunlight, as added heat to epoxy will hasten the hardening process and cause the material to generate a lot of heat, melting or igniting its container.

- [ ] **Workbench**
You should have a sturdy workbench with enough space to be able to work organized and safely.

- [ ] **Timer or clock**
Have a timer or clock nearby, as your resin has a pot life, depending on the ratio of FAST and SLOW hardener, you may need to be fast.

- [ ] **Thermometer**
A thermometer is critical as the temperature should at least be 18°C, otherwise your epoxy will get viscous and will not harden.

Checklist

Molding materials

Materials like fibers and epoxy

Chopped fibers 12mm
There are 2 main choices, chopped carbon fiber, or chopped basalt fibers. I like to use basalt to prototype parts that do not need as high of a strength-to-weight ratio compared to carbon fiber, as this is more environmentally responsible.
12mm Chopped fibers are also a balanced choice, enabling you to make small and big parts. These fibers can still be cut smaller to maybe fill thin features.

Continuous carbon fiber tow
Depending on the part, continuous fibers can be added to the chopped fibers, greatly increasing the part's strength. Increasing the strength-to-weight of the part.

IN2 infusion epoxy + AT30 FAST hardener
Infusion epoxy should be used, this will be critical as excess epoxy as to be able to flow out of the mold. Do be sure to roughly calculate the amount you will need before you start your project.

AT30 FAST and AT30 SLOW hardener
I recommend using a 1/3 FAST and 2/3 SLOW hardener to lengthen the pot life of the epoxy, giving you more time to mold your part, while keeping hardening times within a day.

PVA or similar release chemicals
Your mold surface will have to be coated with a release agent, there are a lot of options, but you should use high quality materials, as opening and re-using the mold will get very hard.

Filleting wax
Filleting wax is used to cover threads or other features where epoxy should not flow but could flow.

Mold fabrication tools and materials

Nuts and bolts
Having a range of bolts and nuts will allow you a lot of flexibility to design your mold.

Checklist

Consumables

Paper cups
You'll need a lot of paper cups to mix your epoxy and weigh your fibers, they'll need to be at least 200ml.

Mixing sticks
Mixing sticks are used to mix your epoxy, these should be sturdy and not flake. Ice cream sticks are a cheap option and will serve their purpose. These can also be used to push down fibers.

Flat bristles
These can be small and cheap nylon bristles, but the most important feature is that they do not lose any hair. These will contaminate your material.

Working area protection
You'll need a protected workbench and floor with either plastic or cardboard.

Paper towels
You will need a lot of paper towels to clean your work area, mold or hands. Always keep these nearby.

PET tape
Used for covering split lines and even mold surfaces.

Tools

Hardware you need to open and close your mold.

3D printed bottle caps
3D printed bottle caps that help you slowly drip your epoxy and hardener out of their container, ensuring you get an accurate measurement.

Table clamps
Clamps to either close your mold or keep your mold closed, these should be very sturdy as they can bend if they aren't stiff enough.

Closing rig
A rig you make yourself or a vise that you can use to close your mold, you will have to put down a lot of force.

Molding

Calculate materials

The strength requirements for your part determine the amount of materials you need. For a typical forged carbon piece, you need to know the density of your carbon fiber and epoxy, as well as the volume of your part. The recommended fiber volume fraction is 60%, which offers an optimal balance of strength, lightness, and stiffness. With a 60% fiber volume fraction, forged carbon **behaves similarly to basic aluminium** in terms of yield strength but is a bit more flexible.

If you adjust the fiber volume fraction, a lower ratio will result in a weaker, more flexible part, which may be easier to handle when closing your mold. Getting these values right is crucial to achieve the desired results. Incorrect calculations can lead to suboptimal fiber volume fractions, affecting your part's performance.

Adding unidirectional fiber is another option to increase strength. While I can't specify exactly how much stronger your part will be, replacing 30% of your fiber volume with unidirectional fiber could result in a significant increase in strength, potentially reaching the levels of carbon fiber weaves under optimal conditions. However, remember that these are best-case scenarios. Personally, I use unidirectional fiber in load-bearing areas to ensure adequate strength. I typically replace 10% of my chopped fiber with unidirectional fiber, but you can adjust this percentage based on your project requirements. Wrapping unidirectional fiber around holes or cylinders can reinforce these areas. When used in longer sections prone to flexing, unidirectional fibers can significantly increase stiffness, potentially surpassing carbon weaves when you replace 30% of chopped fiber with unidirectional fiber.

Technically you could also apply a weave to reinforce the part, but this could hinder fiber flow during molding, as everything has to travel around a bit.

To avoid confusion and errors, I suggest using an **Excel spreadsheet** to automatically calculate the material requirements and keep a record of previously used values. This approach provides consistency and helps you adjust material ratios for future projects, ensuring more reliable results.

You can find the download for this excel in the back of the guide in the **links & files section**.

		g/cm^3
Material properties	Carbon	1.7
	Basalt	2.8
	Epoxy	1.15

Fiber	Skateboard hanger	Part volume (mm^3)	Pure weight (g)	60% Fiber fraction (g)
	Carbon	47825.18	81.30	48.78
	Basalt	47825.18	133.91	80.35

Epoxy	Fraction epoxy (g)	Resin (g)	Hardener (g)	1/3 FAST (g)	2/3 SLOW (g)
	33.00	25.38	7.62	2.54	5.08

Optional fiber reinforcement	Skateboard hanger	10% Continuous fiber (g)	Chopped fiber remaining
	Carbon	8.13	40.65
	Basalt	8.13	72.31

Molding

Key values

Material properties
Mainly the density of your fiber material will be important

Part volume
The volume of the part you are going to mold.

60% Fiber fraction
This value is calculated by: [fiber volume fraction **x** Pure weight of part in carbon]

Fraction epoxy
This value is calculated by: [epoxy volume fraction x volume x density epoxy x 1.5]
The 1.5 ensures that you will have excess epoxy, ensuring all fibers will be wetted.

Hardener
This is normally noted on the box, but is calculated by: (30/100) * Fraction epoxy

Optional fiber reinforcement
It is important to detract the amount of continuous fibers you want to use from the total chopped fiber weight. When using different materials for your fibers, it is important to calculate weights by using volumes.

Checklist

Firstly do a run down of the checklist and see if you have everything, this is critical as once you have started, and you mixed your epoxy and hardener, you can't just stop the process without wasting your materials.

Prepare workspace

Protect what needs to not be ruined for life with plastic or cardboard to prevent permanent damage, this means table, floor vise or closing rig, table clamps (you can use tape).

Organise your workspace in such a way that allows you to easily measure and mix materials.

Keep the paper towels and box of Nitril gloves easily accessible, you will use multiple pair and will have to clean spilled epoxy.

Having an extra person nearby can be helpful, it will allow you to not have to take off your gloves as often.

Piece of paper

Have your piece of paper with all the values you calculated ready and nearby, you may need to check, change or calculate on the fly and do not want to waste any time having to take your laptop and searching for a file.

Molding

1. Apply PVA/mold release

Applying PVA (Polyvinyl alcohol) or mold release is crucial to ensure proper part release.

The application process is similar for most products, be it PVA or RWD mold release:
Apply a **thin** layer, wait 15 minutes until dry, then apply next layer, do this until you have 4-5 layers.

Do not forget to do this for al areas that may come into contact with epoxy:

- Split lines
- Bolts
- Inserts
- Mold halves

2. Assemble mold

Now assemble your mold and try to close it, this should not require any force. If it does not close properly, it could be because of tolerances being too tight and you may need to either sand down problem areas or reprint your mold.

3. Measure fibers

Use an accurate scale to measure the amount of fibers, an accurate kitchen scale will suffice, but I recommend using a scale that measures up to 2 decimals after the comma. These can be bought for very cheap of most e-commerce sites.

If you are using any unidirectional fiber reinforcements, remember to subtract those.

4. Big volumes of resin

When making bigger parts, be very mindful of the amount of resin you are using, When using the slow hardener you should not expect any problems. But when using the fast hardener, even in combination, do not mix big volumes. The hardening process is exoterm, thus is will heat up the volume, speeding up the process even more. A good rule of thumb is that if you use more than 15 grams of FAST hardener, you should probably split your volume epoxy into 2 cups.

You will notice this process when you touch the mixing cup and think to yourself: “this seems to be getting hot.

If this happens, **expect the pot life of the epoxy to be half as long**.

5. Measure resin and hardener

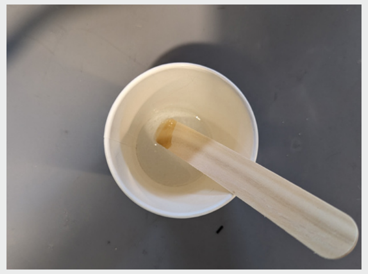
It is very important you get this right, epoxy is very sensitive to mistakes in its ratio and will perform significantly worse if your are even 1% off.

Use the same accurate scale to measure your resin and hardener into the same cup.

I recommend **using the included bottle drip caps** I designed if possible.
Resin is viscous and hard to pour accurately if the opening is big, Hardener on the other hand is very runny and is also easily overshot when pouring.

The drip bottle caps are included in the links & files section in the back of the guide, these should fit on the most common chemical bottles easy composites uses.

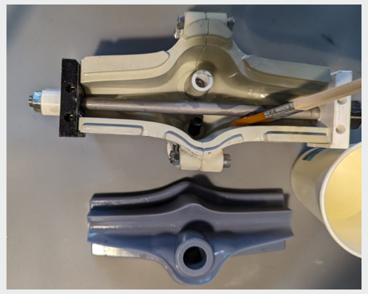
6. Mix thoroughly



Another critical step to getting your epoxy right is mixing it very thoroughly for a a solid minute with a mixing stick that doesn't flake or a resin mixing tool. Make sure to go into all the nooks and crannies of the cup.

If your cup as gaps you can not reach into, you should pour over your epoxy into another cup after mixing.

7. Coat mold surface



Use a brush to apply a generous layer of epoxy to the surface of both mold halves, and the part of the inserts that will touch the forged carbon piece.

Molding

8. Pre-fill thin walls or cavities

Awkward cavities or thin walls should be pre-filled.
Depending on their kind and placement, I recommend cutting some chopped fibers to a length of a few mm for really thin walls for example.

9. Apply layer of fibers

Apply a layer of fibers to all the part surfaces until you can't see the mold surface anymore. This is to counter the formation of holes in your part surface .
Wet your brush with epoxy and wet out the fibers, they should be wet , but do not use too much epoxy.

10. Apply reinforcement fibers

Now is often a good moment to apply your reinforcement fibers, they will be between discontinuous fibers, resulting in a protected, impact resistant, stiff core.
Be sure to also wet these fibers, as they will provide a bulk of your strength.

If your part is symmetrical, you'll want to sandwich your reinforcement fibers between an even layer of chopped fibers.

11. Mix remaining fibers with epoxy

I like to pre-mix my chopped fibers with the remaining epoxy to make sure everything gets to be wetted out, just throw your fibers into the cup with epoxy and mix by hand, put some pressure on them to make epoxy come up in between the fibers. It is very important they are all wet, as your matrix material is what keeps everything together.

12. Evenly distribute the remaining fibers

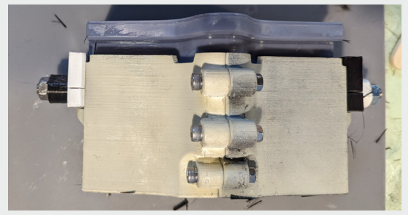
When distributing the remaining fibers, keep in mind the volumes you are trying to fill. They should be filled proportionally, fibers may travel around a bit during compression, but , there is a limit.

Molding

13. Closing the mold

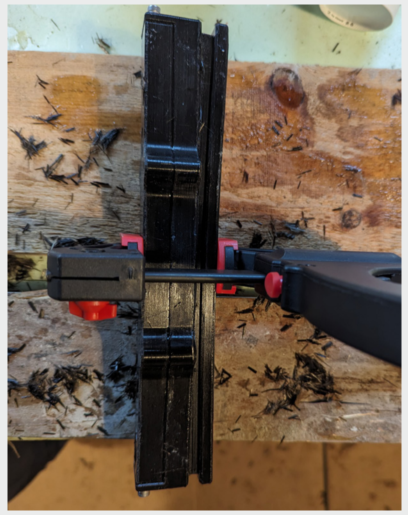
Carefully close the mold, fibers should normally be wet enough to stick to the mold, allowing you to insert the male side into the female side.

While inserting the pieces into each other, be careful to not trap any fibers in-between the raised edge/ compression area. This could make it harder or impossible to close the mold.



14. Clamping

Your mold should be clamped in between 2 thick and hard load distribution plates. This is essential, as your printing material will deform if the pressure isn't distributed across its surface.



15. Clamping tools

There are various ways to close a mold, but using bench clamps can be labor-intensive, especially for larger molds where more clamps are needed.

A large bench vise is a more efficient choice. It allows the epoxy to flow smoothly due to gravity and can exert substantial force for a consistent closure.

Another option is a closing rig, this lets you apply a significant force with a wrench and you can compress multiple molds simultaneously.

If you use a hydraulic press, be careful not to apply too much pressure, as 3D-printed molds can break under excessive force.

Remember to cover any surfaces that might come into contact with epoxy, like floors or hardware, with plastic wrap to prevent messes or permanent damage.

Choose the closure method that fits your mold's size, shape, and the necessary force. And if you're working in a shed or similar space, ensure it's properly protected from epoxy spills.

Just remember that you'll need to keep the mold clamped for at least 8 hours, you can close it with one method an then apply clamps to keep it closed, but be careful to not relieve the mold of pressure, this can create air bubbles in your part.

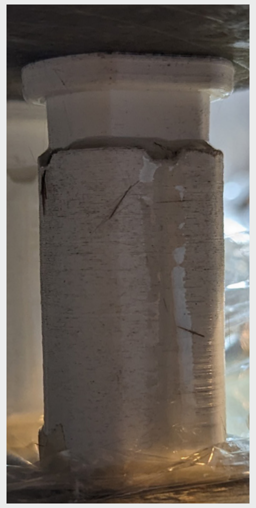
Molding

16. Compression time

A good guideline when compressing the mold is to do it slowly, taking about 10 minutes. This allows the infusion resin to rise through the part and escape from the mold. If the part is larger or more complex, you may need to adjust this time frame.

As the mold compresses, the epoxy is forced out while the fibers remain inside. This process will continue until the mold is fully closed. The absence of epoxy flow could indicate issues such as insufficient pressure, incorrect fiber calculations, or improper mold design, leading to uneven part compression.

To avoid these problems, always check for epoxy flow during compression. This step helps ensure your forged carbon parts are properly formed and achieve the desired fiber volume fraction for optimal strength and performance. If no epoxy flows out, take a moment to assess and correct any issues before proceeding.



17. Curing

Curing epoxy-based parts, such as those made from forged carbon, requires maintaining a temperature of at least 18°C. For optimal curing, place your mold in a sufficiently warm room for at least 8 hours if using FAST hardener, and at least 24 hours for SLOW hardener. If you mix 1/3 FAST with 2/3 SLOW hardener, expect the curing time to be somewhere in between.

Keep in mind that epoxy parts generally reach their maximum strength after about 14 days at a steady 25°C. This prolonged curing enhances the material's mechanical properties significantly.

Always consult the datasheet for your specific epoxy infusion resin for detailed information on curing cycles. The datasheet will provide insights into how different temperatures can affect the curing process and the final properties of the part.

If necessary, you can use a curing oven or another heat source to maintain a consistent temperature, but be careful not to exceed the recommended heat limits as it can degrade the epoxy.

18. Clean up

Keeping your workspace clean is essential when working with hazardous materials like epoxy and carbon fibers. Proper handling and disposal help minimize health risks and environmental impact.

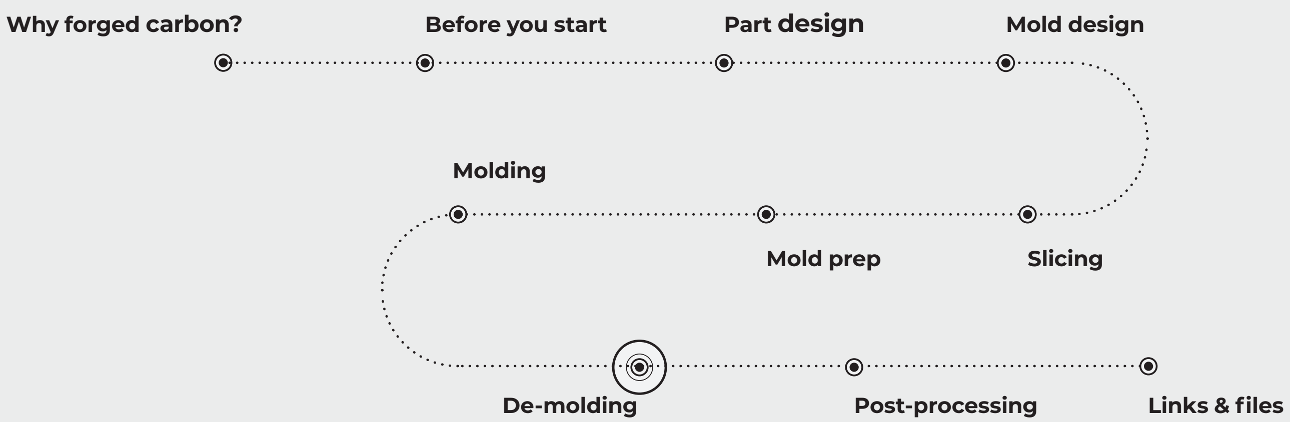
Always ensure any uncured epoxy is fully cured before disposal.
Once cured, it can be thrown into a regular trash bin designated for incineration. If you have excess resin in a cup, do not pour it back into the original container. Instead, add some hardener, let it cure, then dispose of it properly.

Ensure your workspace is ventilated to prevent the buildup of harmful fibers or volatile organic compounds (VOCs). Exposure to these substances can be dangerous if inhaled.

Materials contaminated with epoxy, such as brushes, plastic covers or rags, cannot be recycled and must be disposed of in trash designated for incineration. Make sure to seal the trash bag to contain any fumes or residues while waiting for disposal.

By following these guidelines, you can keep your workspace safe and reduce the environmental impact of working with epoxy and carbon fibers. Regular cleaning and proper disposal practices help ensure a safe working environment for everyone.

Stage 08
De-molding



Important rules

Safety

Wear working gloves, the fibers become razor sharp when cured and even if they do not cut you, fine fibers will enter the skin and irritate you for the coming week.

Safety glasses are also a must, as bits of epoxy and fibers can fly around.

Working environment

Fibers, loose bits of epoxy and other particles will fly around, be sure you can clean these up.

Health

Be extra sure to wear a mask, as particles may release from your part or mold.

Re-use

Always re-use part of your mold if you can, even for other projects. It is unfortunate, but epoxy contaminated parts can not be recycled.

Checklist

Safety gear

- [ ] **Safety glasses**
Resin, fibers and cured fibers can fly into your eyes when filling or opening molds.

- [ ] **Respirator or FFP2 mask**
Resin can emit volatile organic compounds, fibers can get airborne and enter your airways and during sanding or post-processing a lot of dangerous particles can get airborne if you do not wet sand.

- [ ] **Working gloves**
Tough work gloves that can resist sharp fibers will be needed to remove parts from the mold and to do post-processing on the part.

- [ ] **Protective clothing**
Most of your skin should be protected to avoid fibers and epoxy coming into contact with it. So wear long sleeved shirts and long pants, or a lab coat. Also make sure this clothing can be permanently damaged.

- [ ] **Dirty footwear**
Wear shoes that are allowed to get permanently dirty, as epoxy can drip on them.

Working environment

- [ ] **Children and animals**
Your working area should be locked away from children and animals, as you will be working with dangerous substances.

- [ ] **Ventilation**
Your working environment should be properly ventilated, as epoxy can emit volatile organic compounds (VOC's), and carbon fibers are light enough to get airborne and pose a danger to your and other people's health.

- [ ] **Waste bin**
Have a proper waste bin for epoxy contaminated materials and gear. Do keep in mind that you are not allowed to dispose of uncured materials in normal waste.

- [ ] **Workbench**
You should have a sturdy workbench with enough space to be able to work organized and safely.

Checklist

Mold fabrication tools and materials

- [ ] **Sanding paper**
Sanding paper ranging from 60 to 2000, your mold surface will have to be smooth, otherwise your parts will stick to the mold surface.

Tools

- [ ] **Soft hammer**
You may to give “persuade” the mold or part to release by giving it a tap with a soft hammer.

- [ ] **Prying tool**
A tool that fits between the mold split lines and is sturdy enough to receive some light taps from a hammer and be used to pry open the mold.

- [ ] **3D printed bottle drip caps**
3D printed bottle caps that help you slowly drip your epoxy and hardener out of their container, ensuring you get an accurate measurement.

- [ ] **Soft de-molding wedge**
A soft piece of plastic that you can either buy or 3D print, this helps you to open a mold or remove a part from the mold without damaging the mold itself.

De-molding

Mold damage

Your number one priority after safety should be avoiding damaging the mold. Here are some things to be mind of:

- Use soft wedging tool to open the mold
- Use a soft hammer
- When clamping in a vise, cover the jaw plates with a soft material like wood or paper towel.

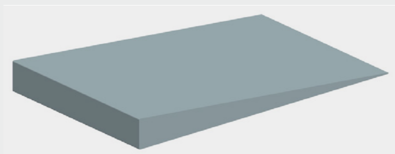
Mount mold

Opening you mold will be a lot easier if you mount the mold in a vise, do be careful to not damage the mold too much, use a soft material to cover your clamping surface.

Tools

There are some tools you'll need, depending on the mold

Soft wedging tool



You will need a soft wedging tool to open your mold without damaging it.
Included in the 3D printable files, you'll find an STL for such a wedging tool, these are good because you can just print more you need to replacement or have a bigger mold
You can also buy these, they will last longer and leave less damage.

Sturdy prying tool

After initially opening the mold with the soft wedging tool you may need something sturdy like a big flat head screw driver to pry it open further.

Bolts

Have the tools ready to loosen all your bolts

Drill

There is always the possibility you will need a drill if something went wrong with the epoxy .

De-molding

Process

1. Remove all bolts

2. Break epoxy seal on split lines

A bulge of epoxy may have formed on the split lines, you should remove these. They created a seal and glue the part together.

3. Remove inserts

You shouldn't only remove the inserts that hinder opening the mold. It can also be beneficial to remove other inserts, as you can handle the part more easily without damaging it when it is in the mold.

4. Soft wedging tool

Line up your wedge on the chamfered split line, and give it some taps with a soft hammer.
Try to evenly open the mold around the split lines.

5. Sturdy prying tool

If the mold doesn't open smoothly, use the sturdy prying tool to down some leverage on gap the wedging tool has formed.

6. Part release

Your part should release from the mold with some taps from the wedging tool.

For parts that are located in a cavity, use the extraction features you have added, use a blunt tool and some hammer taps to drive them out.

If it doesn't, you can attempt to pry it of the the sturdy tool.

De-molding

Part not releasing

If your part isn't releasing from the mold, there might be several reasons:

- Mold finish: The surface of the mold might not be smooth enough, causing the part to stick.
- Undercuts: You might have overlooked an undercut that's trapping the part.
- Inadequate mold release: The mold release coating might not have been applied properly.

Fixes

Temperature changes

Putting the mold in either the freezer or an oven can help. Because carbon composites have a lower thermal expansion rate than most materials, heating the mold may allow it to expand enough to release the part. Be cautious not to exceed 50-60°C, as this can deform PLA molds due to their glass-transition temperature. Heating the mold and then attempting to remove the part might work, but handle with care to avoid damaging the mold or burning yourself.

Also be aware by doing this you will be annealing your mold, making it a lot stronger, something you may not want to do if part is stuck and you may need to break your mold. Even SLA prints will get stronger when heat treated.

Freezing the mold

This technique is useful if inserts or smaller components aren't releasing from their cavities. Cooling the mold can cause the printing material to contract more than the carbon composite, allowing the part to release. Be sure to monitor the mold for any signs of stress or deformation caused by rapid temperature changes.

Directly heating printed part

Depending on the kind of printing material, it may be possible to melt away the material or make it malleable enough the pry it out of your part. Do be careful with a flame near the epoxy parts, is the epoxy will burn when it a direct flame. A simple lighter can do the trick, but using a torch will be a lot faster.

Break mold around part

When all else fails, you may need to just completely break the mold or insert.
If possible use a thick wood chisel, hit it with a hammer in between the layer lines.
It may also be possible to drill out inserts until they are thin enough to be melted or pulled out.

Re-using the mold

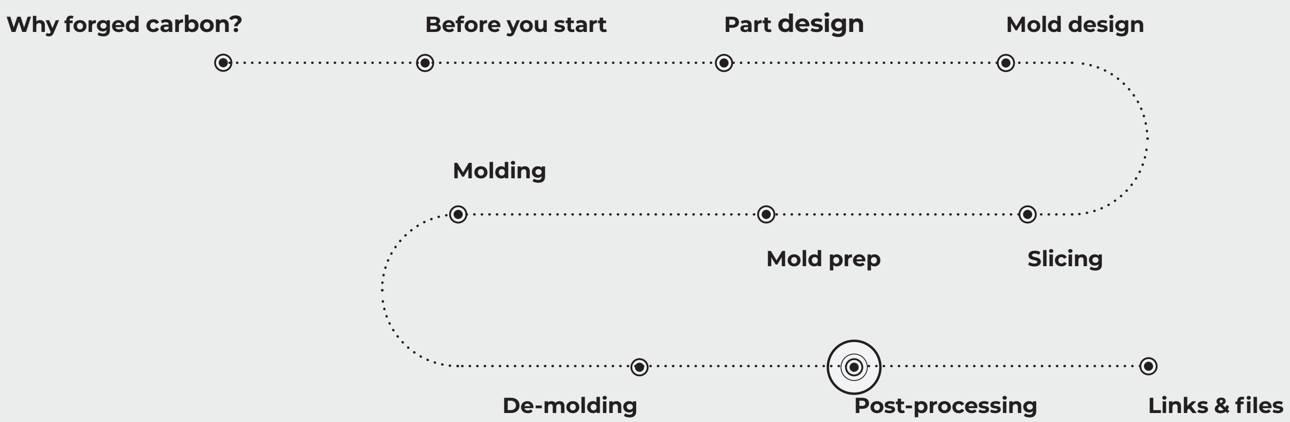
To re-use the mold you need to sand away any left over epoxy, **use a mask and ventilated space for this, these epoxy particles are very cancerous.**
Use **wet sanding** on top of the other measures, this greatly lessens contamination of your air and workspace.

Split lines and surface should be clean and flat again.

Give the mold a wash to remove particles that may contaminate your next part.

If a bolt is covered in epoxy, you can run it through thread cut tool, if you do not own one, a metal bolt and some force can also do the job.

Stage 09
Post-processing



Important rules

Safety

Most critically, wear at least an FFP2 mask during this stage and use **wet sanding** to limit the particles released into the air.

Wear working gloves, the fibers become razor sharp when cured and if they do not cut you, fine fibers will enter the skin and irritate you for the coming week.

Safety glasses are also a must, as bits of epoxy and fibers can fly around.

Working environment

Fibers, loose bits of epoxy and other particles will fly around, be sure you can clean these up.

Health

Be extra sure to wear a mask, as particles may release from your part or mold.

Checklist

- [ ] **Safety glasses**
  Resin, fibers and cured fibers can fly into your eyes when filling or opening molds.

- [ ] **Respirator or FFP2 mask**
  Resin can emit volatile organic compounds, fibers can get airborne and enter your airways and during sanding or post-processing a lot of dangerous particles can get airborne if you do not wet sand.

- [ ] **Nitril gloves**
  During the molding stage and while handling a non post-processed part, you'll need to wear either Nitril, vinyl or latex gloves, ranked from ideal to good enough. Repeated contact with epoxy can cause skin irritation and can cause you to become allergic to the substance. Carbon fiber also easily enter the skin, causing irritation.

- [ ] **Working gloves**
  Tough work gloves that can resist sharp fibers will be needed to remove parts from the mold and to do post-processing on the part.

- [ ] **Protective clothing**
  Most of your skin should be protected to avoid fibers and epoxy coming into contact with it. So wear long sleeved shirts and long pants, or a lab coat. Also make sure this clothing can be permanently damaged.

- [ ] **Dirty footwear**
  Wear shoes that are allowed to get permanently dirty, as epoxy can drip on them.

Mold fabrication tools and materials

- [ ] **Sanding paper**
  Sanding paper ranging from 60 to 2000, your mold surface will have to be smooth, otherwise your parts will stick to the mold surface.

Checklist

Working environment

- [ ] **Children and animals**
  Your working area should be locked away from children and animals, as you will be working with dangerous substances.

- [ ] **Ventilation**
  Your working environment should be properly ventilated, as epoxy can emit volatile organic compounds (voc's), and carbon fibers are light enough to get airborne and pose a danger to your and other people's health.

- [ ] **Cleanliness**
  Ideally your working environment should be clean and dust free, as technically, particles that enter your composite can weaken the material.

- [ ] **Working area protection**
  You'll need a protected workbench and floor with either plastic or cardboard.

- [ ] **Chemical storage**
  Your chemicals and dangerous materials should be properly stored and locked.

- [ ] **Waste bin**
  Have a proper waste bin for epoxy contaminated materials and gear. Do keep in mind that you are not allowed to dispose of uncured materials in normal waste.

- [ ] **Fire safety**
  Have a fire extinguisher nearby, epoxy can overheat and start a fire.

- [ ] **Direct sunlight**
  Your working environment should not be exposed to direct sunlight, as added heat to epoxy will hasten the hardening process and cause the material to generate a lot of heat, melting or igniting its container.

- [ ] **Workbench**
  You should have a sturdy workbench with enough space to be able to work organized and safely.

- [ ] **Timer or clock**
  Have a timer or clock nearby, as your resin has a pot life, depending on the ratio of FAST and SLOW hardener, you may need to be fast.

Checklist

Molding materials

- [ ] **IN2 infusion epoxy + AT30 FAST hardener**
Infusion epoxy should be used, this will be critical as excess epoxy as to be able to flow out of the mold. Do be sure to roughly calculate the amount you will need before you start your project.

- [ ] **AT30 FAST and AT30 SLOW hardener**
I recommend using a 1/3 FAST and 2/3 SLOW hardener to lengthen the pot life of the epoxy, giving you more time to mold your part, while keeping hardening times within a day.

- [ ] **Epoxy coating resin**
An epoxy specific for coating a carbon fiber part or to fill voids left after molding.

- [ ] **Clear coat spray paint**
Can act as a clear coat, increasing surface finish and add contrast to the fibers

Tools

- [ ] **3D printed bottle drip caps**
3D printed bottle caps that help you slowly drip your epoxy and hardener out of their container, ensuring you get an accurate measurement.

Checklist

Consumables

- [ ] **Paper cups**
You'll need a lot of paper cups to mix your epoxy and weigh your fibers, they'll need to be at least 200ml.

- [ ] **Mixing sticks**
Mixing sticks are used to mix your epoxy, these should be sturdy and not flake. Ice cream sticks are a cheap option and will serve their purpose. These can also be used to push down fibers.

- [ ] **Flat bristles**
These can be small and cheap nylon bristles, but the most important feature is that they do not lose any hair. These will contaminate your material.

- [ ] **Working area protection**
You'll need a protected workbench and floor with either plastic or cardboard.

- [ ] **Paper towels**
You will need a lot of paper towels to clean your work area, mold or hands. Always keep these nearby.

Post-processing

Flash

In post-processing, one of your first tasks is to remove the flash from your piece. Flash is excess material that forms along mold seams due to resin leakage during compression and curing, creating jagged edges.

A box cutter is a useful tool for trimming flash. Use a sharp blade with controlled cuts to avoid damaging the part or cutting yourself. Cut-resistant gloves are a must, as flash can be sharp and contain embedded fibers.
Give the edges a sand down with some sanding paper.

Mounting part

When mounting your forged carbon part, keep these tips in mind to avoid damage:

Avoid damage from sharp edges: If you're using clamps or other mounting hardware, ensure that any sharp edges are covered with a soft material, like rubber or fabric. This prevents the carbon composite from getting scratched or gouged during mounting.
Don't over-tighten clamps: Composites are excellent in tensile strength but can crack under excessive pressure. When clamping, apply just enough force to hold the part in place. Over-tightening can lead to cracks or other damage.
These precautions will help maintain the integrity of your carbon composite parts during the mounting process. If in doubt, always use a softer touch and consider alternate methods for securing your parts that won't risk damaging them.

Holes

When drilling holes in forged carbon composites, remember that cutting through fibers can weaken the part. Use universal drill bits; the composite is soft, so specialized tools aren't necessary. Drill with care to avoid damaging the surrounding fibers.

After drilling, check for signs of fraying or weakening. If needed, reinforce the area with epoxy to maintain strength.

Post-processing

Threads

Forged carbon composites are not ideal for threaded connections, as cutting into the material can weaken it and cause fibers to fray. If you need threads, it's better to use metal inserts or create threaded holes during molding.

If you do decide to cut threads into the composite, use a proper tapping tool and work slowly to minimize damage. Keep in mind that these threads will likely wear out faster due to the material's softer nature.

For stronger, more reliable threads, consider adding inserts during the molding process or using press-fit inserts after curing. This approach maintains the composite's integrity and provides a more durable connection.

Clean part

Your part may be covered in PVA and or a layer of wax, it is important you clean this off, use soapy water, scrub well, as the contamination can hinder later processes.

Inserts

Inserts in forged carbon composites can serve various purposes beyond creating threaded connections. They add functionality, strength, or specific properties to a part. Here's how different inserts can be used:

- Threaded inserts create strong attachment points for bolts or screws, either by molding or pressing them in after curing.
- Friction bearings reduce friction in moving parts.
- Metal reinforcements add strength to specific areas.
- Alignment or locating inserts ensure parts fit together accurately.

When using inserts, ensure they are compatible with epoxy and resistant to corrosion. Aluminium, for example, can react with epoxy, leading to corrosion or degradation. This is due to the chemicals in epoxy affecting aluminium's oxide layer, which is meant to protect the metal. Over time, this can weaken the bond or cause failure.

Choose materials like stainless steel, brass, or specially coated aluminium for inserts to avoid these issues. If aluminium is used, consider coating it with a corrosion-resistant material or adding a barrier layer to prevent contact with epoxy. This helps maintain the durability and integrity of your composite parts.

Post-processing

Filling voids/ pin holes

When filling voids or holes in a forged carbon composite part, you need a method to contain the epoxy and ensure a smooth finish. Here's a reliable approach to filling voids:

Block off the area by using clear PET tape (or similar) to create a barrier around the void. This will prevent the epoxy from flowing away, allowing it to stay in place while it cures.

Carefully pour or inject epoxy into the void, ensuring it fills the space completely. If the void is large or deep, you may need to add epoxy in layers, allowing each layer to cure before adding more.

Cover with tape: After filling, cover the filled area with PET tape to create a smooth surface and prevent dust or debris from contaminating the epoxy as it cures.
Choose the right epoxy: You can use coating epoxy or regular epoxy for this task. If you're working with regular epoxy, adding a FAST hardener allows the epoxy to cure in 6-8 hours, letting you continue working on the part sooner.
Remove the tape: Once the epoxy has cured, carefully remove the tape. Sand the area if needed to ensure it's smooth and level with the rest of the part.

Turning

Forged carbon is easy to turn and machine. High-speed steel (HSS) cutting tools or standard bits work well for most tasks. Here are some quick tips:

- Sharp tools: Ensure your tools are sharp to prevent chipping and rough edges.
- Gentle pressure: Forged carbon is softer than metals, so light pressure is enough. Heavy force can damage the composite.
- Common operations: Facing, grooving, and drilling are straightforward. Keep the tool moving smoothly.
- Avoid overheating: Excessive heat can soften the composite. Use moderate speeds and avoid friction.
- Safety gear: Wear goggles and a dust mask, and ensure proper ventilation to avoid inhaling fine particles.

Post-processing

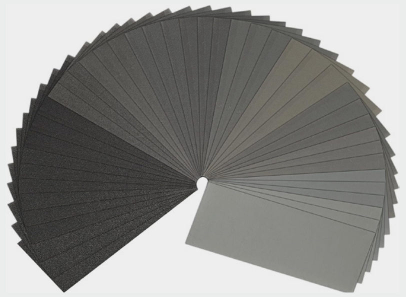
Milling

Milling has completely the same characteristics as turning.

Sanding

Sanding is a key part of post-processing for forged carbon composites, though it's not always critical. The main goal is to smooth sharp edges to make them safe and refine the surface as needed. Here's what to consider when sanding your composite parts:

- Wear a dust mask or respirator, goggles, and gloves to protect yourself from harmful particles. Make sure your workspace is well-ventilated to minimize the inhalation of dust and fibers.
- Begin with coarser grits (80-100) for initial smoothing and gradually move to finer grits (320-800) for a polished finish.



- Flat surfaces: To sand flat surfaces, place your sanding paper on a hard, flat surface and rub your part on it. This technique ensures even sanding and maintains the part's flatness. Alternatively, you can use a sanding block for more control.
- Apply even pressure while sanding to avoid low spots or irregularities. Pressing too hard can cause damage, especially on thinner or more delicate sections of the composite.
- Wet sanding reduces dust and keeps the surface cool, helping to prevent overheating during sanding. It's especially useful for achieving a smoother finish on intricate or delicate parts.

- Do progress checks as you sand, periodically check the part to ensure you're achieving the desired smoothness and safety. Address any sharp edges or rough spots to make sure the part is safe to handle.

If you want that bit of extra finish, do a polish on the sanded surface, it will not be shiny, but does increase contrast in de fibers, creating that beautiful look.

Post-processing

Coating en polishing

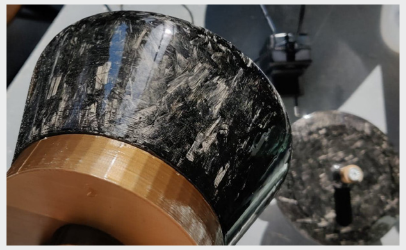
When it comes to finishing forged carbon composites, you have a couple of options. You can opt for a clear spray coat, which is a quicker and easier solution. However, this approach offers less protection against UV rays, and the finish might not be as durable or as smooth as an epoxy coating.

Epoxy coating, on the other hand, provides a more robust and UV-resistant finish. It's designed to be clear and to bring out the contrast in carbon fibers, enhancing the aesthetic appeal of your part. However, it requires more time and effort to apply correctly, as it involves careful preparation and application techniques.

Here's what to keep in mind for **epoxy coating**:

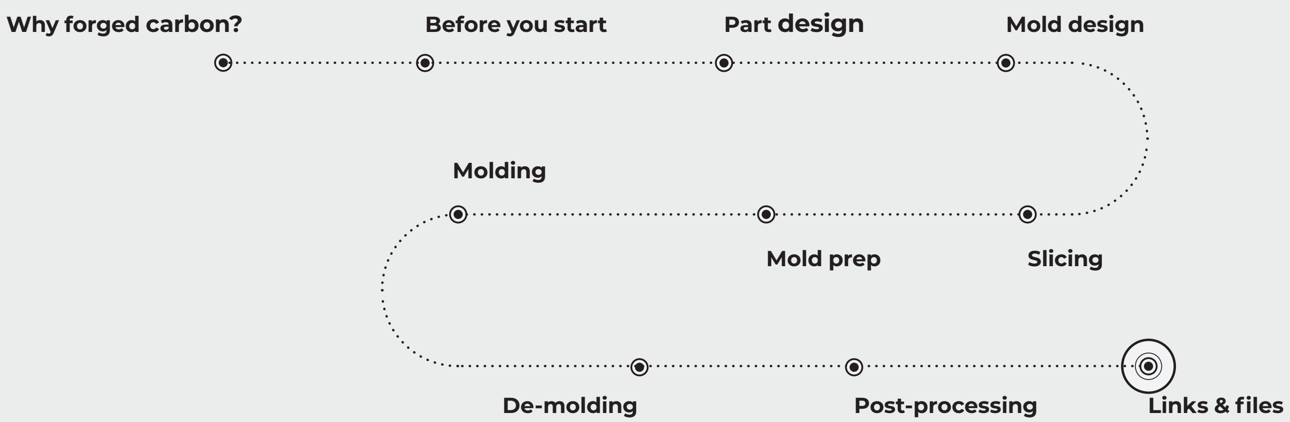
- **Use coating resin:** Choose a resin specifically designed for coating to ensure a smooth, clear, and durable finish. Regular epoxy won't give you the same results.
- **Prepare the surface:** Lightly sand the composite to create a rough texture for better adhesion. This step is crucial to ensure the coating bonds properly.
- **Be aware of complexity**: Epoxy coating is a more complex process, requiring precision and patience. If you only need a basic protective layer, a clear spray coat might be enough, but for a higher-quality finish, epoxy is the way to go.

For a detailed guide on how to apply epoxy coating, refer to the QR code on the right. This links to a tutorial video that provides step-by-step instructions and tips for achieving the best results.



Examples

Stage 10
Links & files



Links & files

3D models tools

Bottle drip caps
https://www.thingiverse.com/thing:6599157

De-molding wedge
https://www.thingiverse.com/thing:6600359

Download the guide here!!

List of consumables

Cups:
https://shorturl.at/oU459

Sanding paper:
https://www.thingiverse.com/thing:6599157

Sanding paper:
https://www.amazon.com.be/gp/product/B085QCYMRY/ref=ppx_yo_dt_b_asin_title_o08_s01?ie=UTF8&th=1

Mixing sticks:
https://www.amazon.com.be/gp/product/B093HHHPR7/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1

Brushes:
https://www.amazon.com.be/gp/product/B08YYWZGZK/ref=ppx_yo_dt_b_asin_title_o01_s01?ie=UTF8&psc=1

Cheap accurate scale:
https://t.ly/3jZYV

Google spreadsheet material calculation

Material calculation sheet:
https://docs.google.com/spreadsheets/d/1syfsIexJM57AYS75UpPdNC7_j_NG2-15qR_txOo_6po/edit?usp=sharing

Thank_you.

Thanks to Easy Composites for their helpful videos, which initially sparked my interest in working with forged carbon. Their resources have been a great starting point.

Thank you for diving into this tutorial on forged carbon composites. I hope it has given you useful insights and inspired you to start your own projects. If you have any feedback or questions, please share them with me. Your input is crucial for improving this guide.

I'll keep this guide updated with the latest information and techniques as they become available. Remember, mastering composites takes practice, but with persistence, you'll achieve great results.

Good luck with your projects, and happy forging! I'm excited to see what you create.

LinkedIn
www.linkedin.com/in/Brent-Cornelis

Behance
https://www.behance.net/brentcornelis

E-mail
Brent.cornelis333gmail.com