

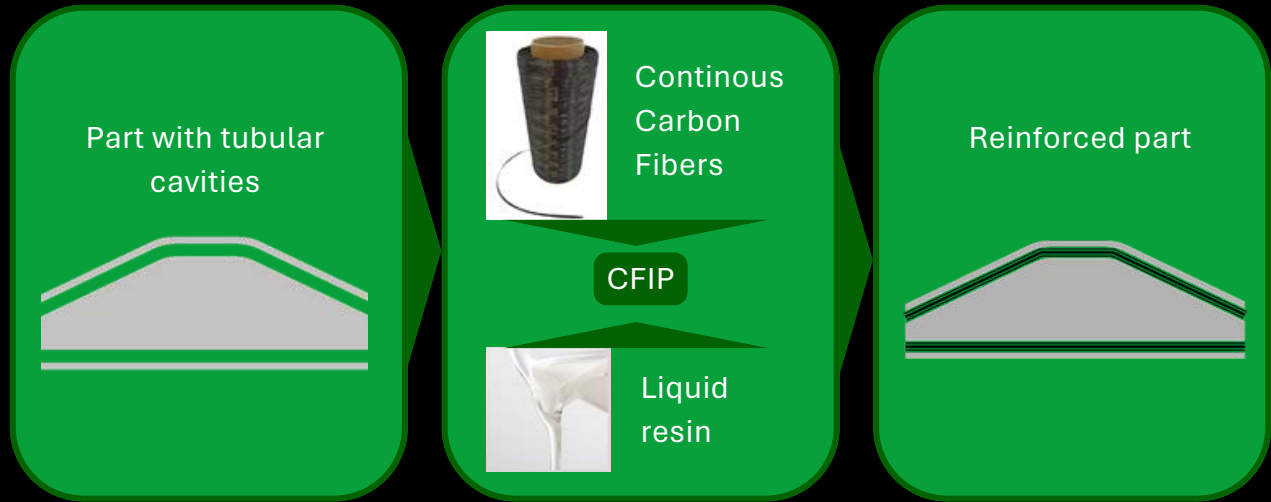


REINFORCE 

DESIGN GUIDELINES FOR  
**CFIP TECHNOLOGY**

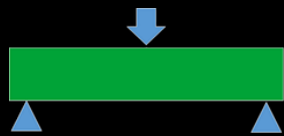


# 1. INTRODUCTION

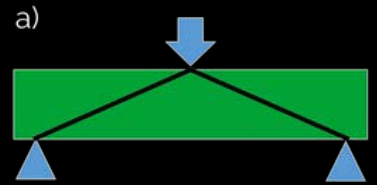


# 2. DESIGN OF THE FIBER TRAJECTORIES

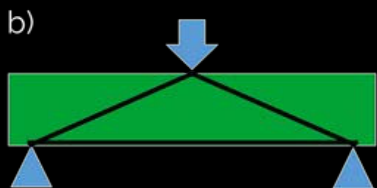
Main design rules:



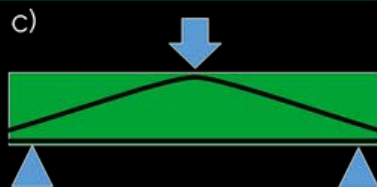
a) **Connect the loading zones** with the supports.



b) **Place separated fibers** where the moments are higher, to maximize stiffness and strength.



c) Meet the **CFIP process constraints**.





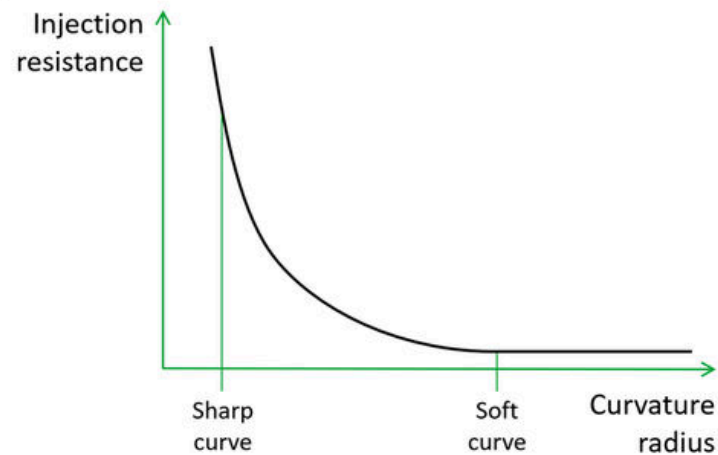
### 3. CFIP PROCESS FUNDAMENTALS

The performance of the injection process is mainly dominated **by the friction that the fibers produce on the cavity walls.**

The friction increases exponentially **when the curvature radius is lower.** The higher the friction the more sensitive is the injection process to possible imperfections or rests of powder at the cavity wall.

Then, **the higher the curvature radius the higher the injection performance,** especially in terms of maximum injection length, velocity and success rate. For this reason, it is recommended **to design low radius curvatures only where needed.**

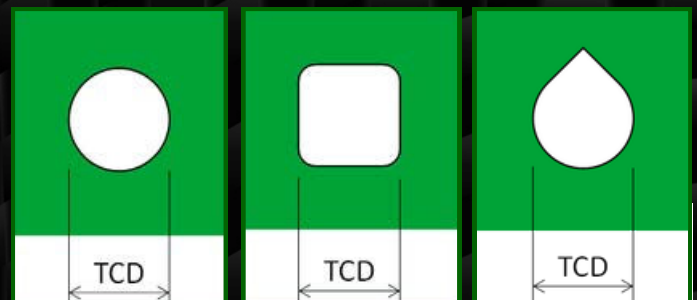
The following principles enable the CFIP process. On one hand, the injector applies **push force on the fibers.** On the other hand, the **simultaneous injection with pressurized resin** generates a flow that **lubricates the cavity** (reduces the friction) and **drags the fibers.**



For this reason, the watertightness of the cavity is also an important factor.

### 4. CFIP PROCESS CONSTRAINTS

- Tubular Cavity Diameter (TCD): 4, 6 or 8 mm.
- Minimum curvature radius\*:
  - Cavities of 4 and 6 mm -> 20 mm.
  - Cavities of 8 mm -> 30 mm.
- Maximum injection length:  $200 \times \text{TCD}^{**}$
- The cavities cannot intersect between them.
- A minimum wall thickness is needed for ensuring the watertightness and strength of the cavity.
- Section shapes: circular, squared or droplet.
- An inlet for each tubular cavity is needed for coupling the injector.



\* The higher the curvature radius, the higher the injection performance.  
 \*\* For trajectories with curvature radius of at least two times the minimum.  
 The injectability can be evaluated with the CFIP Design Checker.

## 5. AM RELATED ASPECTS

The quality of the AM part has a significant impact on the CFIP process performance. Below are described some recommendations; however, it is advisable to manufacture a sample to accurately assess these factors based on the specific manufacturing technology, machine, material, and parameters used.

### MANUFACTURING TOLERANCES

- **Oversize the TCD** in order to counteract the manufacturing tolerances. Typical values:
  - **Powder Bed Fusion (MJF, SLS, SLM)** and Stereolithography (SLA, DLP): + 0.2 mm.
  - **Fused Filament Fabrication (FFF)**: + [the diameter of the printing nozzle].

### SURFACE ROUGHNESS AND DEFECTS

- **Avoid support material inside** the tubular cavities.
- **Optimize the process parameters** to minimize the surface roughness and the risk of defects inside the tubular cavities (especially important for FFF).

### CLEANLINESS

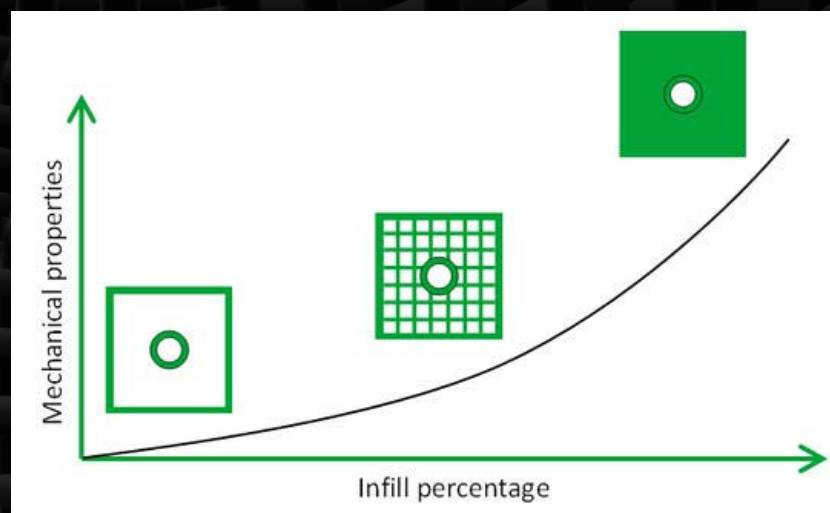
- **PBF: Empty the powder from inside the cavities** and remove the rests of powder adhered to the walls.\*
- **Stereolithography: Clean the interior of the cavities before post-curing the part by injecting solvent inside and drying it with compressed air.\***

### WATERTIGHTNESS AND STRENGTH

- Design the cavity walls thick enough to ensure that they are sufficiently strong and watertight. Typical values of **minimum wall thickness**:
  - PBF, Stereolithography: 1 mm.
  - FFF: 4 lines.

### INFILL

- The infill has an **important influence on the mechanical performance** of the final part. Define its density accordingly.



\*Ask Reinforce3D for recommended cleaning procedures.



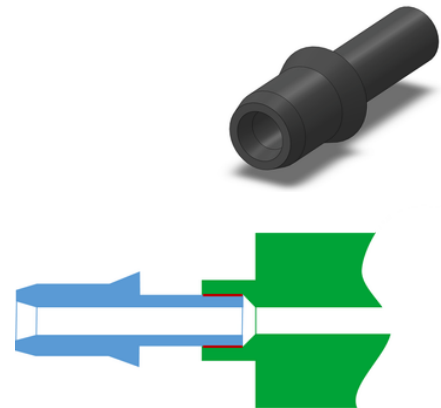
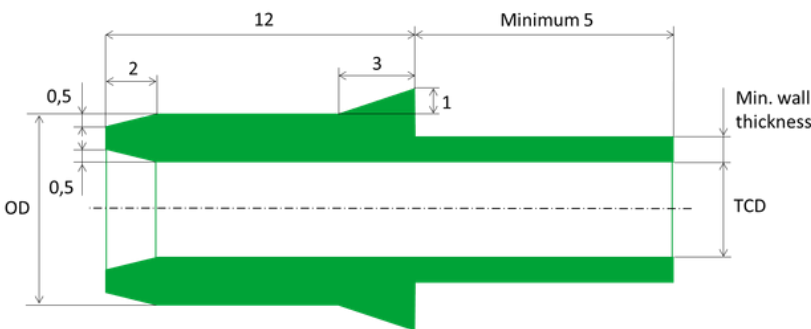
# 6. DESIGN OF THE INJECTOR COUPLINGS

One injector coupling for each cavity is needed for attaching the part to the CFIP machine.

The outer surface needs to be soft in order to ensure the **watertightness at the coupling**. If this cannot be achieved the inlet can be printed by separate and then glued.

Ask Reinforce3D for the 3D models of the inlets.

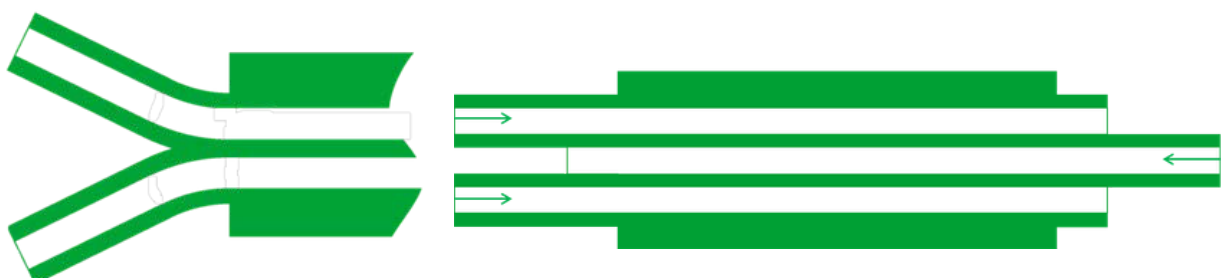
TCD	OD
4 mm	8 mm
6 mm	10 mm
8 mm	12 mm



The injector couplings should have enough space around to allow the connection of the fitting and avoid interference with the injection head. **This can be achieved leaving enough distance** between adjacent inlets.

If the distance between cavities need to be shorter, the couplings **can be separated outside the part or alternated between both ends** of the part.

Ask Reinforce3D for the 3D model of the injection head.



## 7. DESIGN OF THE OUTLETS

The outlets can be:



a) As the inlets or smaller in terms of outer diameter and length (at least 1 x TCD).



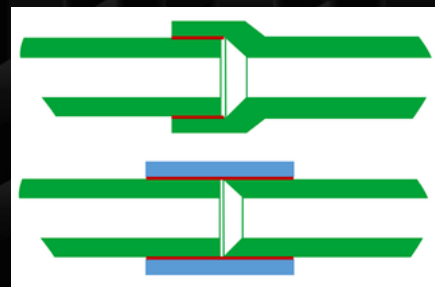
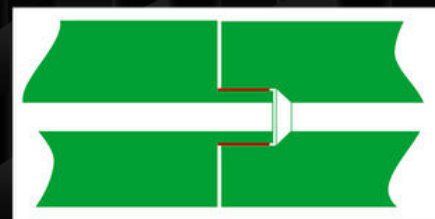
b) The cavity can also be blind. In this case a small orifice (e.g. 1.5 mm diameter) is needed for allowing the air to go out during the injection process. This option complicates the powder removal in PBF, especially for small TCD.

The inlets and outlets need to be cut after the injection and curing process. It is important to ensure proper **access to cutting and finishing tools to facilitate this step.**

## 8. DESIGN FOR INTEGRAL JOINING

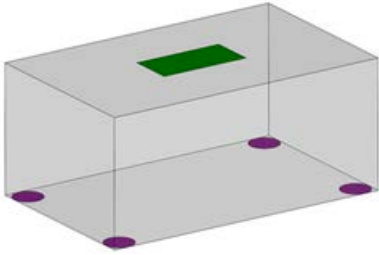
Besides reinforcing, CFIP technology can also integrally join different parts by injecting the continuous fibers through them. Three main criteria must be followed when **designing for integral joining**:

- Ensure a good alignment with soft transitions between parts. Chamfers in the direction of the injection are recommended.
- Ensure the watertightness of the joint, which can be achieved by designing a tongue-and-groove joint and applying adhesive.
- When different cavities are not aligned to the same assembly direction, is recommended to use inner or outer flexible tubes for enabling the assembly.



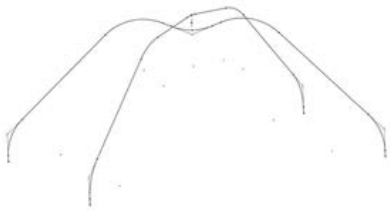
## 9. DESIGN METHODOLOGY

This **methodology** can be followed for designing CFIP parts:



1.

**Place the points for the inlets and outlets** precisely at the reference geometry (e.g. using 2D sketches).



2.

**Draw the fiber trajectories** through the design space connecting inlet and outlet points. 2D and 3D sketching tools are useful for this. It is preferred to draw polylines controlling the radius, although splines can be also used (the minimum radius should be checked).



3.

**Sweep a surface** for each trajectory according to the defined section and TCD.



4.

**Solid modelling adding wall thickness** to the surfaces or removing material from the reference geometry.



5.

**Add the couplings and outlets.**

*Revolutionizing the carbon fiber reinforcement*

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 [reinforce3d.com](https://reinforce3d.com)

 [support@reinforce3d.com](mailto:support@reinforce3d.com)

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