# Non planar deposition strategies for Cartesian FDM printers: towards real 3D printing

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## Background

With the goal to reduce the weight and fuel consumption of passenger aircrafts, as well as improving the lifecycle of end of life products, the current industrial trend of aircraft OEMs is to switch thermoset polymer materials to thermoplastic. An example of this trend cab be found with the composite curved panel components for cabin interiors (cf. Fig. 1): in the context of European research funded CleanSky 2 programs, project MAYA aims to use this substitution as an opportunity to find a more automated industrial integration way for the fixation of the brackets on the panel. Currently these brackets are manually placed in the mold during the infusion.

*Fig. 1 – Picture of an aircraft thermoset composite interior panel and brackets*

With a business model based on limited series with as many variations as aircrafts models, the cost of rapid design iteration becomes prohibited with injection molding, while additive manufacturing instinctively answers this problematic. Moreover, the composite interior panel cannot withstand high injection pressures due to the honeycombed structures use to reduce its mass.

## Non planar deposition on a composite panel

FDM is the most commonly accessible technology and offer a wider range of polymers, including aerospace validated materials such as PEI. Indeed, a pellet based solution directly injected or transformed into FDM filament does not require a long and complex safety review for usage approval, sometimes taking years. Most FDM machines, in particular those designed for high performance materials, are based on a Cartesian motion system in a physically or virtually closed design space.

Extrusion heads are guided alongside 3 axes (X, Y, Z) to deposit fused material in beads on a plane (X, Y) then move on to the next flat plane (Z) and keep building the part layer by layer. Most slicer software, used to generate a geometrical code read by the machine use this approach to build parts which sometime presents draft angles or overhang surfaces forcing the addition of support materials.

Our objective was triple : find a deposition strategy allowing for as little rework as possible (i.e. no supports to remove), directly print on a curved surface, and locally enhance mechanical performances using filament orientation.

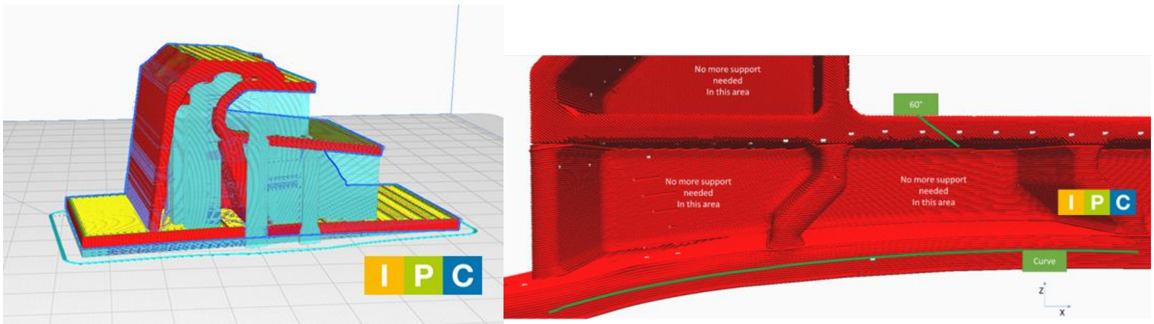


*Fig. 2 – planar slicing with support (left), nonplanar slicing free of support (right)*

Using a machining toolpath software in association with a post processor to translate a gcode readable by a carthesian FDM machine, we introduced non planar deposition on a curved surface at the base of our part (cf. Fig. 2). The curve used for guiding the deposition stops at a determined height after a determined build volume, where a planar printing then takes over. However, the printing plane is oriented at a specific angle to allow a manageable overhang thanks to rapid cooling suspended mid-air, thus allowing the absence of supports. This piece requires a clever design in order to build on at least existing partial layers. The junction between the 2 planes is crucial for a good adhesion, and any space may result in an immediate delamination of the layers in contact.

A deposition on variable plane allows a last enhancement : better local mechanical performances. Several angles can be use to orientate the plane in a 3D space depending on mechanical needs, and deposited beads do not necessarily have to be deposited in a straight line or over continuous length.

These possibilities allows several elements such as larger contact surfaces, sometimes tending toward longitudinal, where efforts are better locally distributed rather than being limited to a single uncontrolled angle. This angle can be exploited to create weaknesses as well, enabling maximum anisotropy for easy disassembly, or emulate macro isotropy by creating complexe paths crossing axis X,Y and Z in near equal lengths.

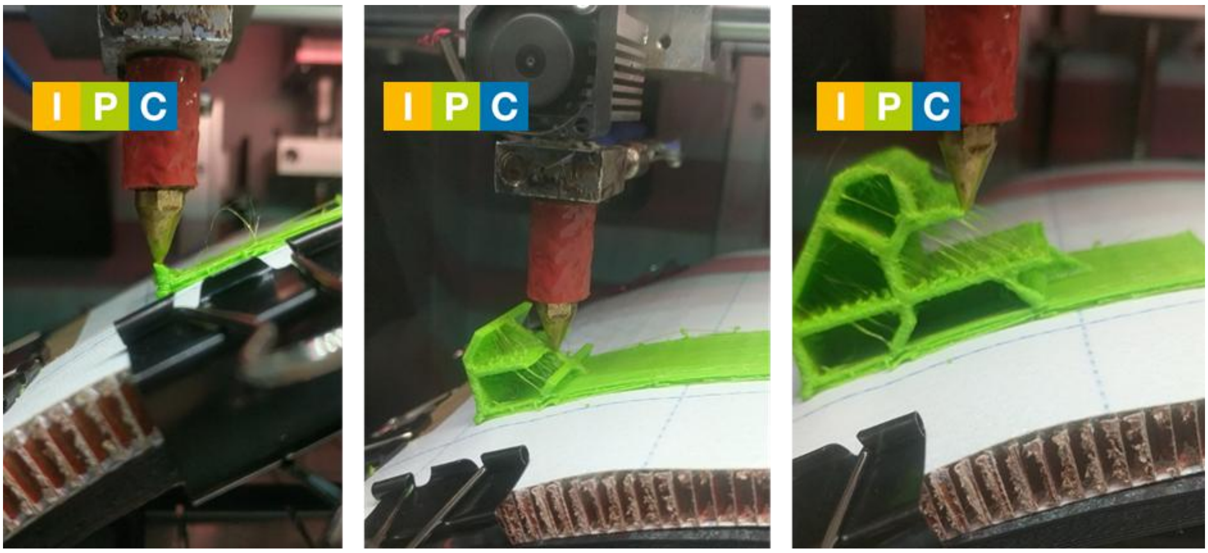

*Fig. 3 – Non planar print steps: following curvature (left), inclined deposition angle (middle and right)*

## Conclusions

The flexibility offered by FDM finds an entirely new dimension when used in conjonction with what could be qualified as real 3D printing. At this stage of the project, the method is in place, and the mechanical characterization is ongoing with results expected by the end of 2021, allowing for extensions in deposition strategies, including in situ repair of composite panels.