ADAPTIVE EXTRUSION NON-PLANAR SLICING

FOR ROBOTIZED FFF

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Robotized Fused Filament Fabrication (R-FFF)

Tangential Continuity Method applied to R-FFF

One of the major drawbacks in the FFF process is the poor adhesion at the interface of adjacent filament and therefore the low mechanical performances in the stacking direction (ST) of the printed part [1].
Several studies have been conducted at IRT Jules Verne to improve ST mechanical properties focusing on building strategy. An innovative approach has been proposed based on the orientation of the extrusion nozzle to exert maximum pressure on the previous layer using a robotic arm and its 6 degrees of freedom. Robotized FFF (R-FFF) consists in adding an extrusion head to the arm which allows specific toolpath to be generated and 6D orientation of the nozzle.
The tangential continuity method developed in concrete 3D printing ([2]) allows wider interface areas between each material deposition layer and thereby maximizing layer adhesion. For each layer the nozzle is specifically oriented according to the direction of the next one (*Fig 1*).

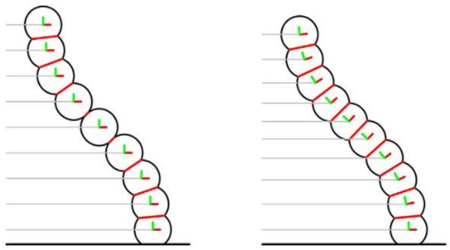

Fig. 1 - Schematic cut perpendicular to layers 3D printed using the cantilever method commonly found in commercial 2D slicing software (left) and the tangential continuity method (right). [2]

One of the benefits of this approach is the possibility to avoid printing support material in the process, as the extrusion direction is no longer Z oriented but tangential to its coincident layer. This method also prevents overhanging extrusion.
Once applied to R-FFF process various constraints need to be managed such as the size and the part complexity and collision risks between the 6D moving nozzle and the part itself. Therefore, the slicing must be adapted from a planar (*Fig. 1, grey lines*) to a non-planar strategy.

Non-planar slicing: high curvature part

One of the use cases that benefits from non-planar slicing is a highly curved parts (*Fig.2, left picture*).

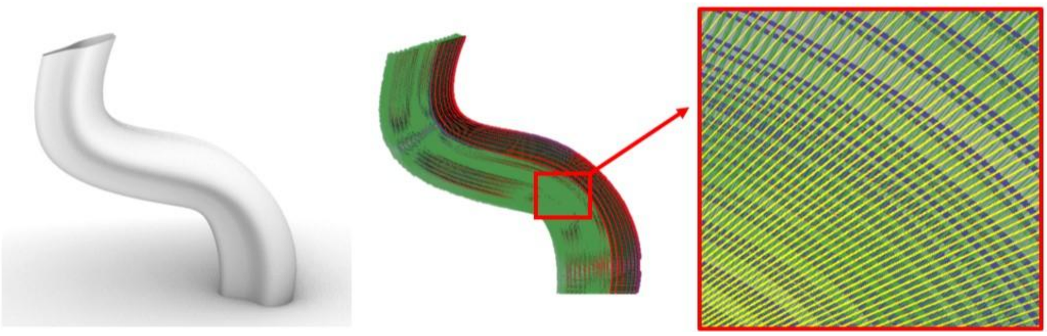

Fig. 2 – High curvature part, slicing of the part with a non-planar strategy, non-parallels yellow layers

In conventional FFF process, such geometry would imply the printing of supports and the sole use of the tangential continuity method would not be processable with a planar slicing. The proposed approach relies on the slicing of the part in the direction determined with tangential continuity method considering the orientation of the layers themselves rather than the nozzle only. Non-planar slicing induces variable material volume deposition inside each layer: on the right picture of *Fig 2* one can see that the space between the slicing planes (yellow lines) changes accordingly with the curvature of the part.

Adaptive extrusion

To ensure the good adhesion between the printed layers and to avoid under or over-extrusion, the deposited volume must be adapted to the expected geometry path (*Fig 3. Left picture*).

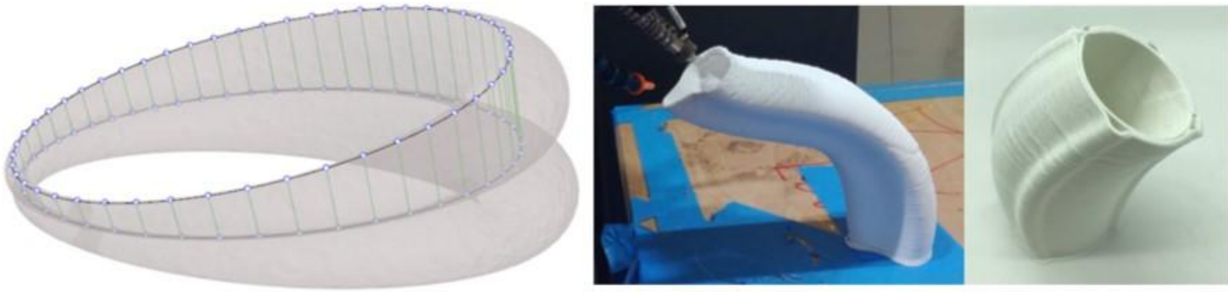

Fig.3 – Adaptive extrusion non-planar slicing 3D printing examples

A dedicated algorithm has been developed to determine the exact volume deposition that is expected at each point of the part to be printed by the robot. The program generates a robotic toolpath associated with its specific extrusion commands for a given part.

Conclusions

This adaptive extrusion ability combined with non-planar strategy allows printing highly curvature pipe and a double pipe (*Fig 3.*) with no support and improved apparent mechanical performances that still has to be quantified

Getting rid of supports opens the door to new opportunities in 3D printing:

- Avoiding material and cleaning costs: reducing the number of operations to be done on the part and reducing the risks of breakage;
- *In situ* 3D printing: the robotic arm to adapt its printing paths according to almost any substrate orientation;
- Adding functionalities: the possibility to print onto a given complex existing part.

References

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AKNOWLEDGEMENT

This study is part of the FACT project managed by IRT Jules Verne (French Institute in Research and Technology in Advanced Manufacturing Technologies for Composite, Metallic and Hybrid Structures). The authors wish to associate the industrial and academic partners of this project; Respectively AIRBUS, ARKEMA, DAHER, DEDIENNE, (EOS), LIEBHERR, SAFRAN, ZODIAC Engineering, TOBECA, CANOE, LTN, PIMM, CNRS, ENSAM et Université de Nantes