COMSOL CONFERENCE 2015 GRENOBLE

MINES Douai

TPCIM Technologie des Polymères et Composites & Ingénierie Mécanique

Optimal Design Of Fused Deposition Modeling Structures using Comsol Multiphysics

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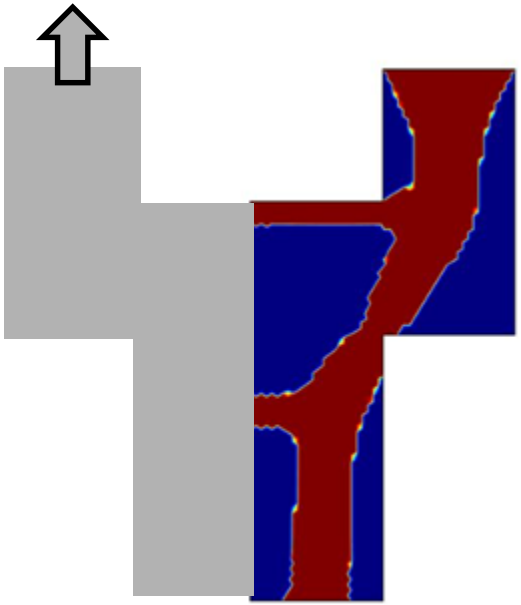
Optimal design and manufacturing strategy for 3d printing

Step 1

Topological optimisation

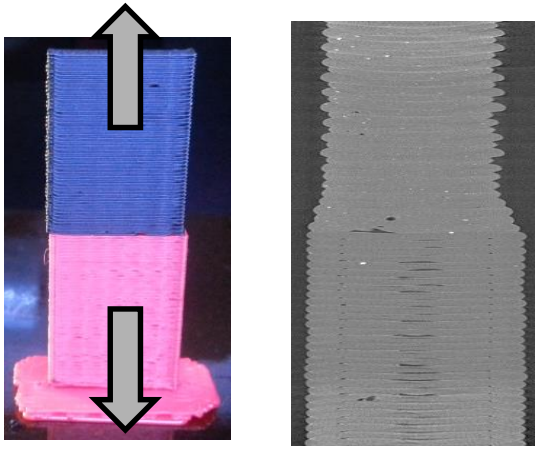


Reduce weight
Optimal stiffness

Step 2

Optimal infill

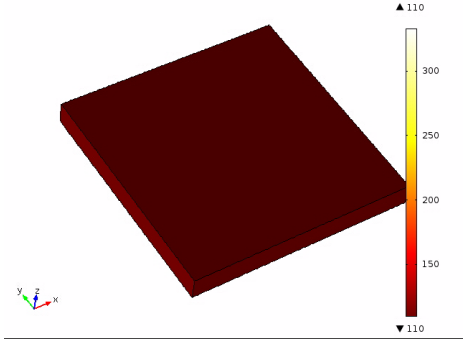
Interface resistance and microstructure



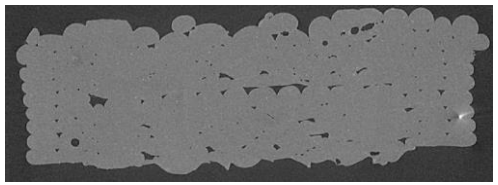
Optimal interface resistance

Step 3

3d printing Heat transfer modelling

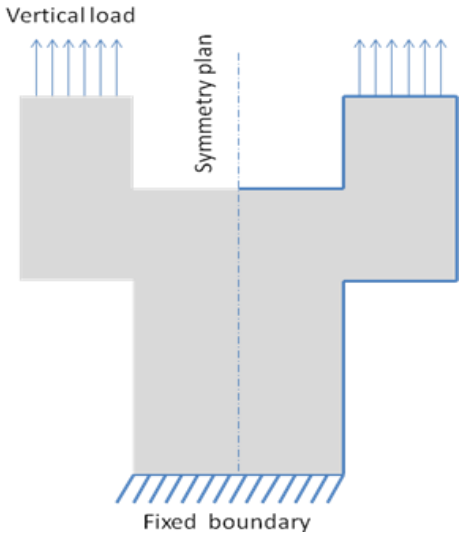


Optimal filaments adhesion



Step 1 Optimal outer design : topological optimization

Topological optimization: Solid Isotropic Material with Penalization (Bendsoe 1989)

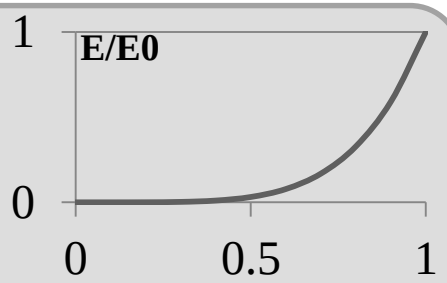


Objective: Minimise weight and maxime stiffness

Maximal surface : $0 \leq \int_{\Omega} \rho_{design}(x) d\Omega \leq 0.5A$

$E(x) = \rho_{design}(x)^p E_0$

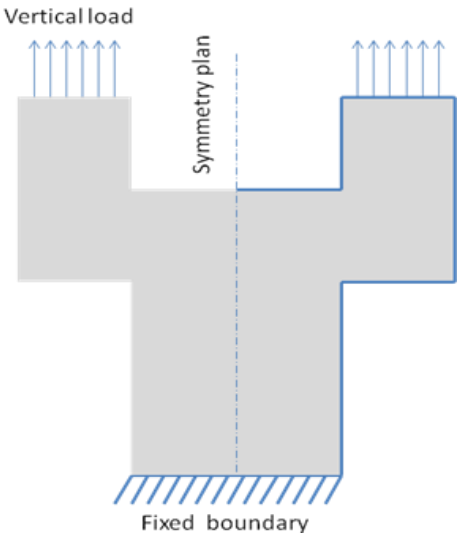
$10^{-9} \leq \rho^p \leq 1$ et p=5

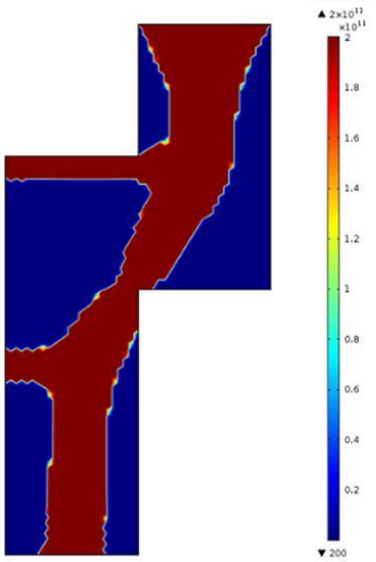


minimise $f = \frac{(1-q)}{Ws_0} \int_{\Omega} W_s(x) d\Omega + q \frac{h_0 h_{max}}{A} \int_{\Omega} \left|\nabla \rho_{design}(x)\right|^2 d\Omega$

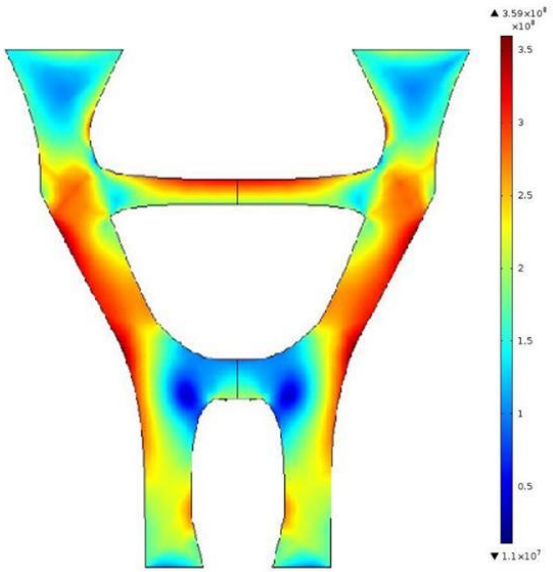
Step 1 Optimal outer design : topological optimization

Topological optimization : Solid Isotropic Material with Penalization

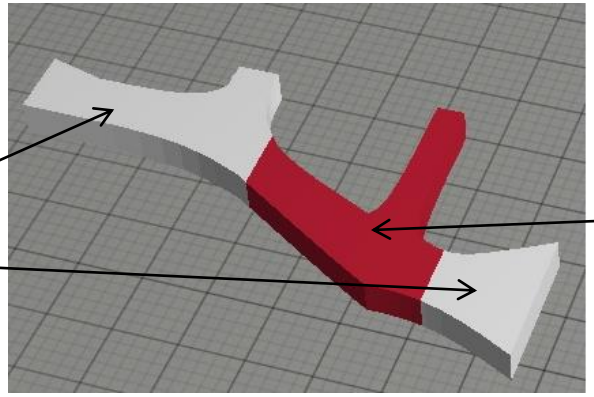




Young modulus (Pa)



V_{mises} stresses (Pa)



Step 2 Optimal infill: heterogeneous infill / multi materials

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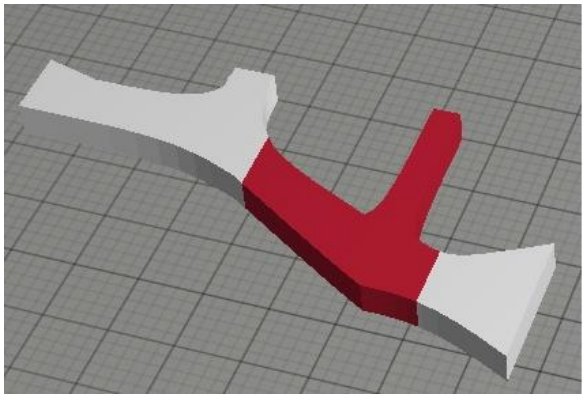
Optimize manufacturing patterns (inner structure)
with outer optimal geometry



Two materials structure

?

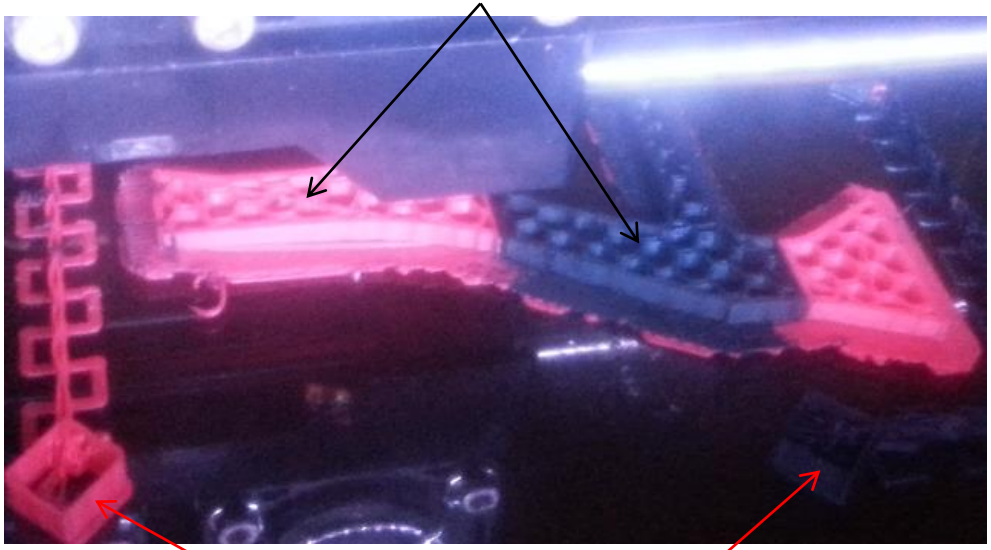
Heterogeneous infill structure

Step 2 Optimal infill: multi materials

Two materials structure with Fused deposition modelling

Manufacturing

Honeycomb structure



Purged walls used
before extruder changing

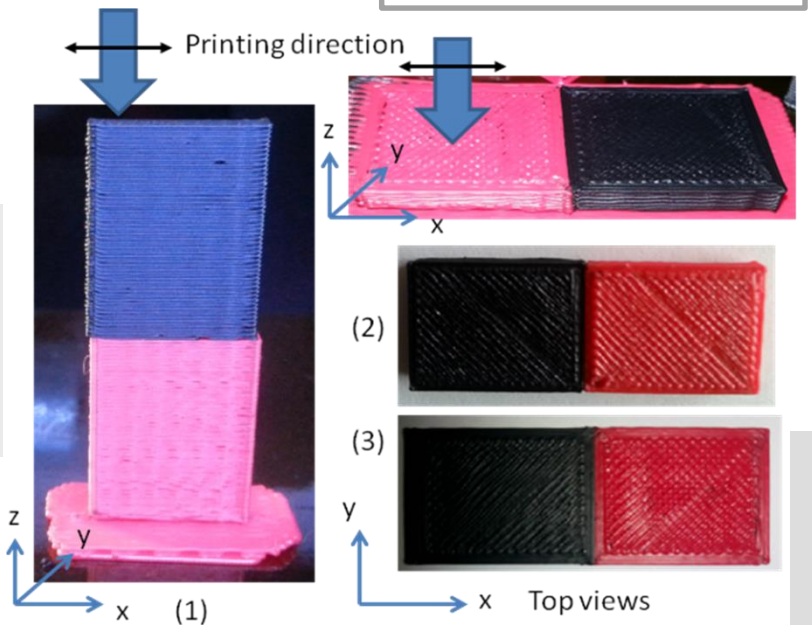
Interface resitance ?

Step 2 Optimal infill: multi materials

Two materials structure printed by Fused Deposition Modeling : **interface resistance ?**

Vertical Position

Horizontal position



Effect of part positioning effect on the printing platform?

Interface ?

Side by side position (zero gap)

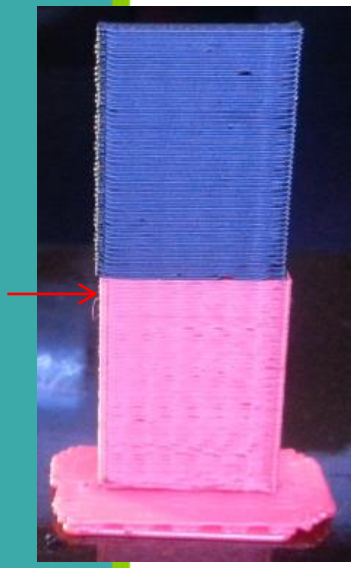
Layers interpenetration of materials at the interface

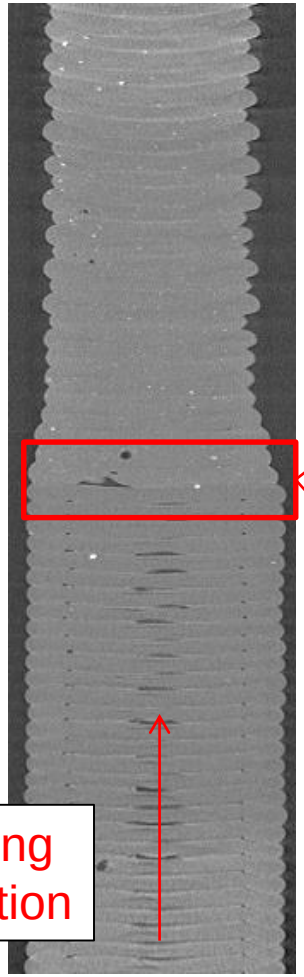
Tensile tests

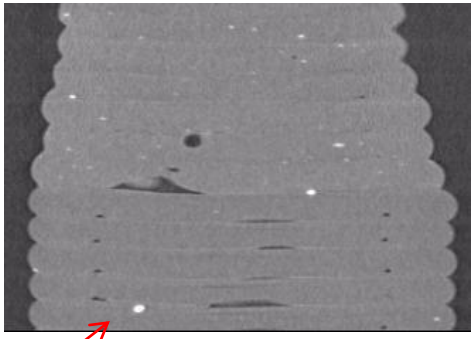
	Two materials			One material	
Sample configuration	1	2	3	Black ABS	Red ABS
Position on platform	vertical	horizontal	horizontal	horizontal	horizontal
Ultimate stress (Mpa)	3.2	0	6.24	10.55	23

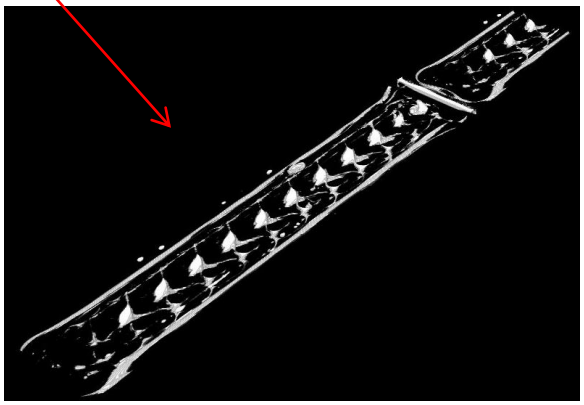
Step 2 Optimal infill: multi materials

Two materials structure printed by Fused Deposition Modeling : **microstructures?**

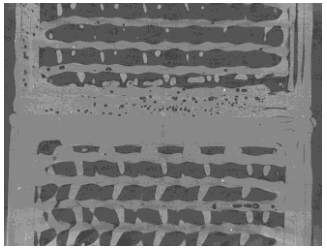


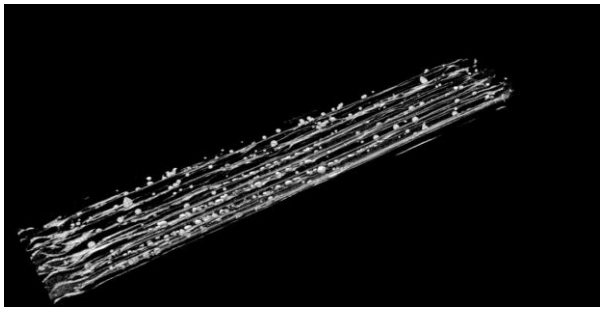






Voids distribution

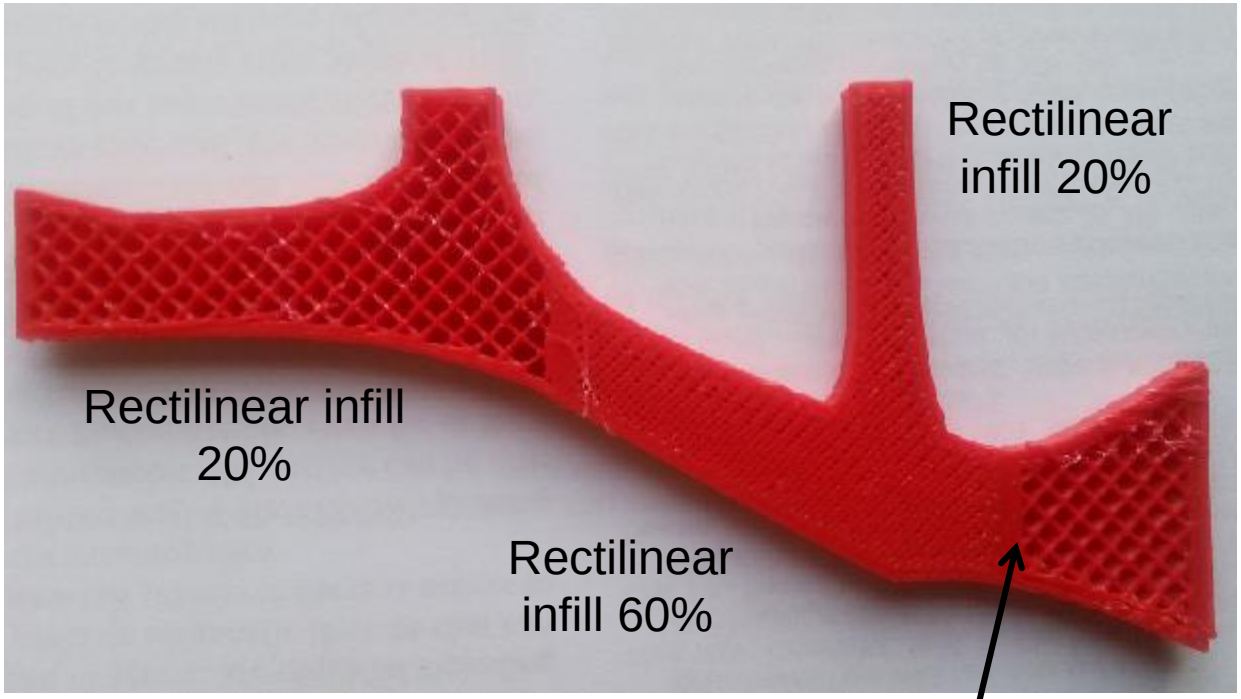




Voids distribution

Step 2 Optimal infill: heterogeneous infill

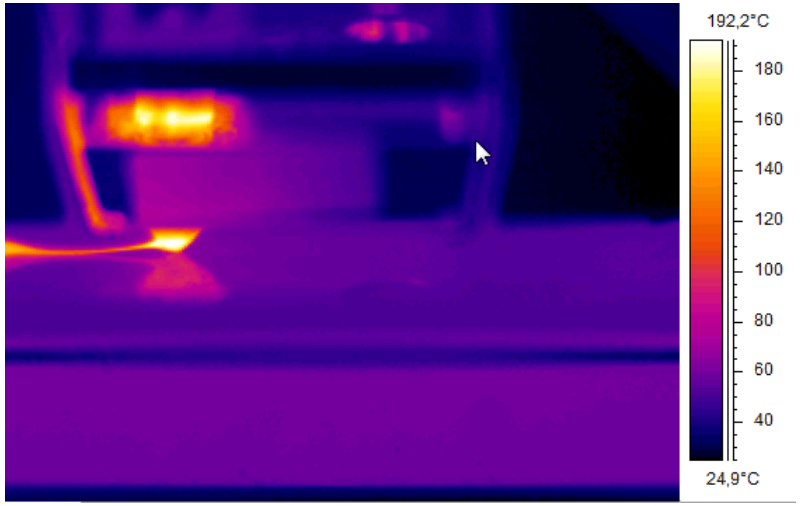
Optimized part manufacturing (inner structure)
with optimal outer geometry



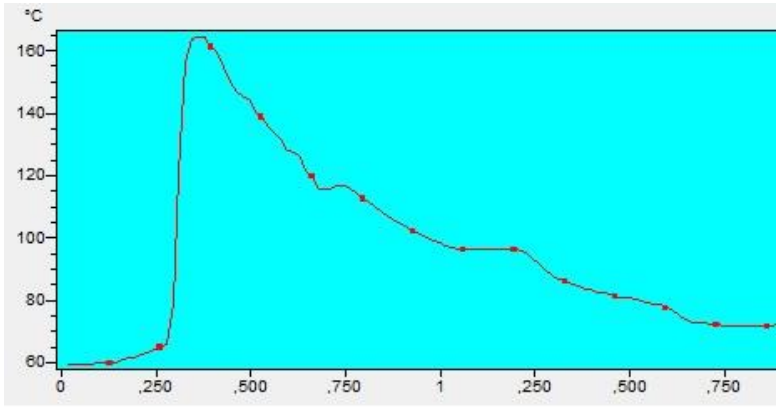
Good adhesion with one material with side by side placed parts

Step 3 FEM modelling : heat transfer

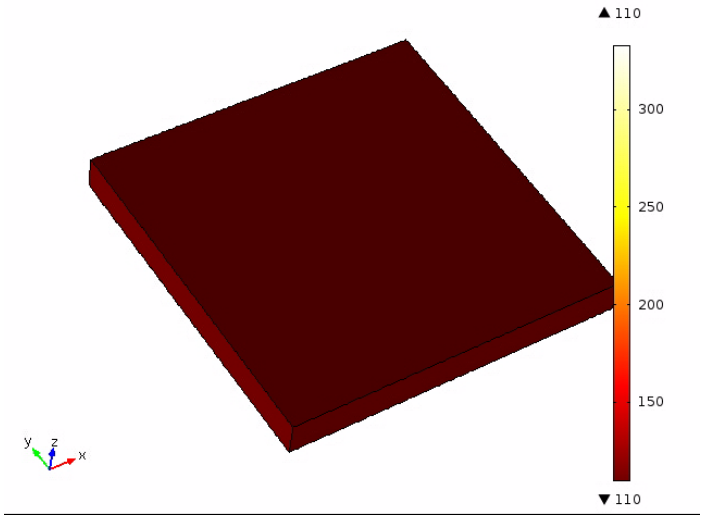
Simulation of Fused Deposition Modeling for optimal infill patterns

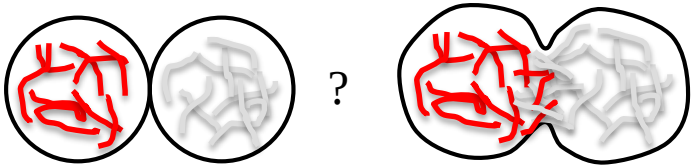


Infrared thermography



Thermal cycle

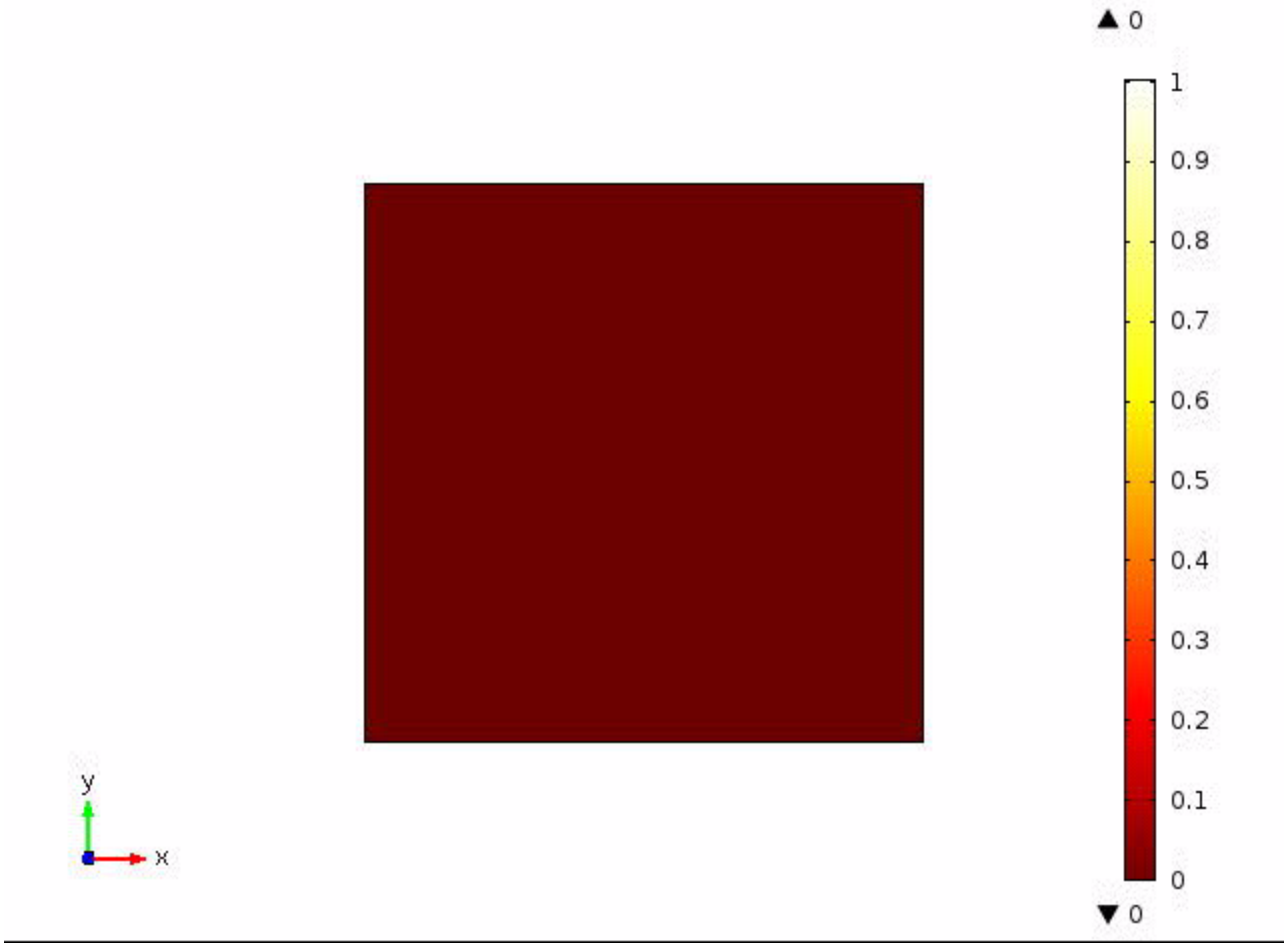




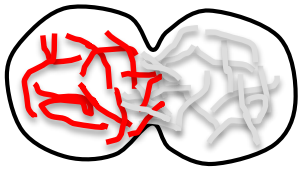
Adhesion between filament

Step 3 FEM modelling : heat transfer

Simulation of Fused Deposition Modeling for optimal infill patterns



Extract patterns with possible coalescence

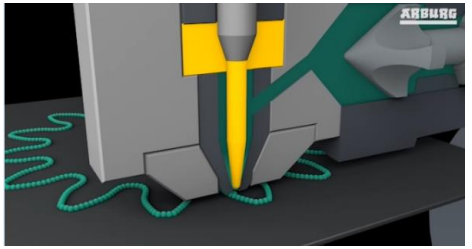


$T>T_{ref}=140°C$

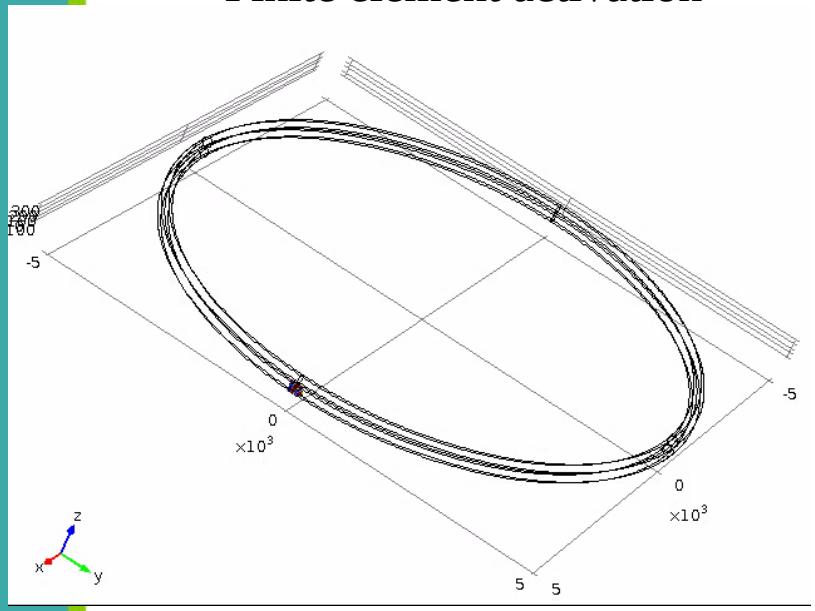
Step 3 FEM modelling : heat transfer with material deposition

Simulation of freeforming (Freeformer Arburg) for optimal infill patterns

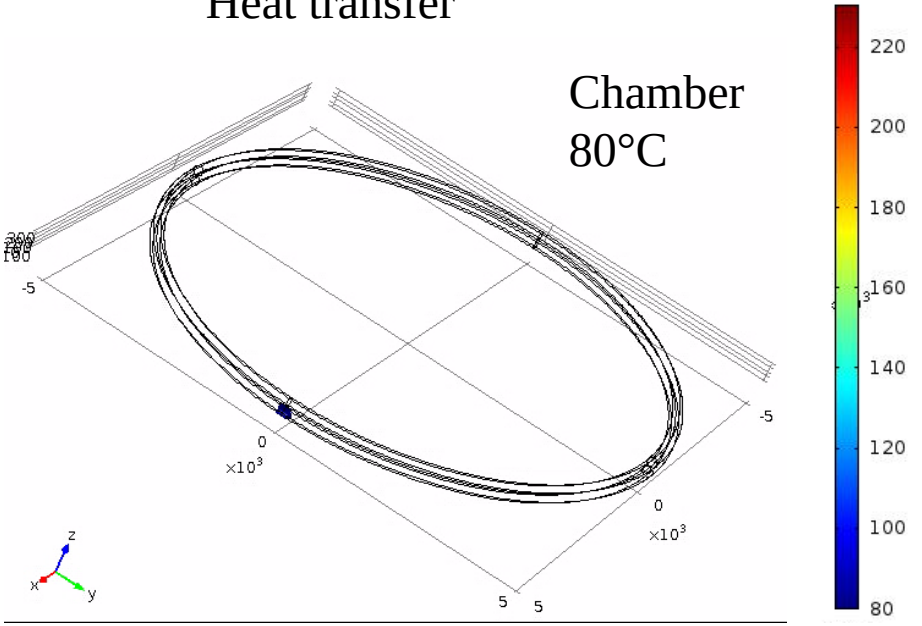
Deposition of 2 circular patterns at 40mm/s et 80mm/s, droplet (ABS) diameter 200 microns



Finite element activation



Heat transfer



155 droplets / circle of radius 5mm,

200 000 degree of freedom

Conclusion and perpectives:

-Optimal part shape can be obtained by topological optimization

-Optimal Inner structure can improve part resistance :

-Adding a high strength materials in critical areas
-Choosing the right layers orientations
-Increasing infill density in critical areas

-Heat transfer and material deposition modeling can help to find best infill patterns strategy to maximise filaments adhesion

-Next steps:

-Modeling of filament wetting and adhesion
-Modeling of stresses and strains during and after 3d printing

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Thank you for your attention

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