



The relevant scale for mechanical modelling in additive manufacturing technologies

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SWISSTECH CONVENTION CENTER

COMSOL
CONFERENCE
2018 LAUSANNE

Basics of FE simulation in structural mechanics

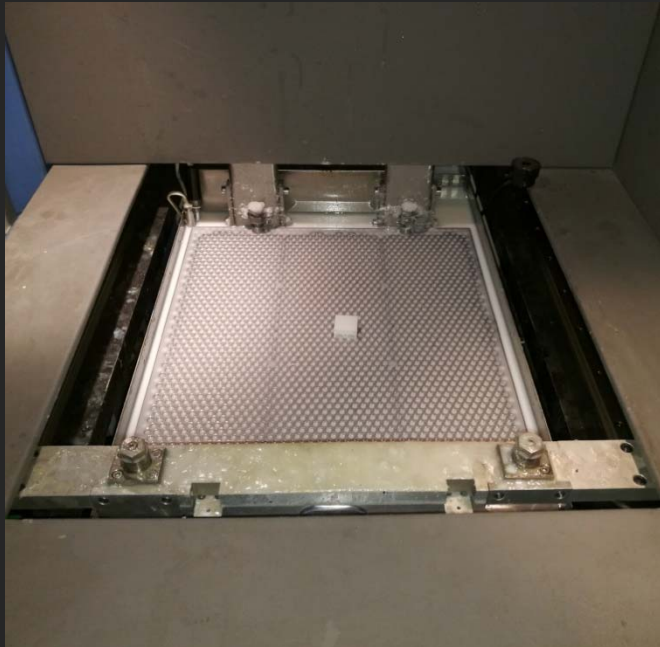
Complex load/geometry + simple mechanical law

Complex mechanical response + simple load configuration

Complexity in both mechanical law + configuration

Source of complexity: material discontinuities

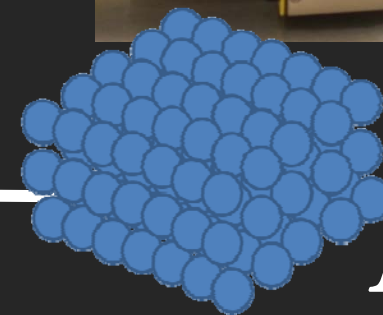
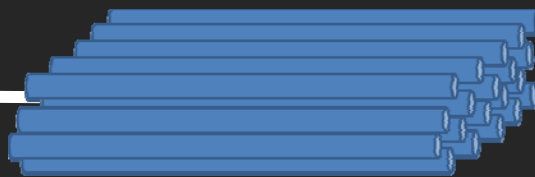
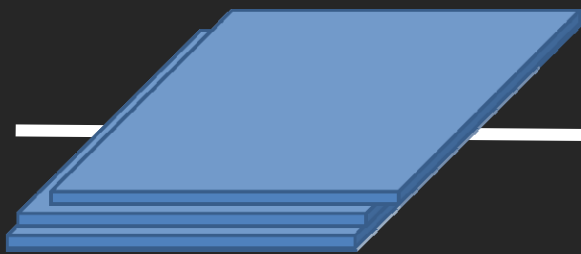
Stereolithography



Fused filament (FDM)



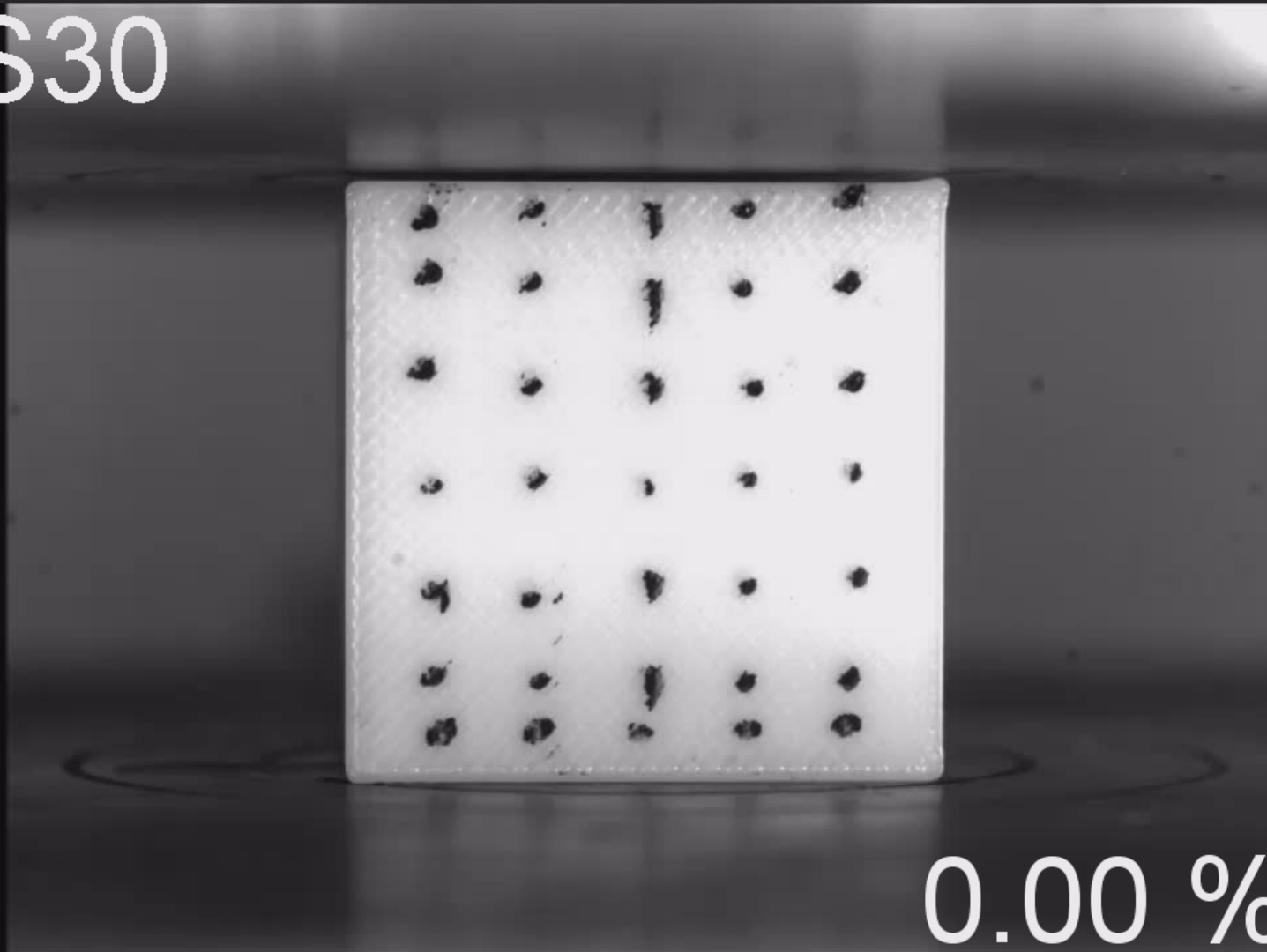
Droplet-based



Material discontinuity

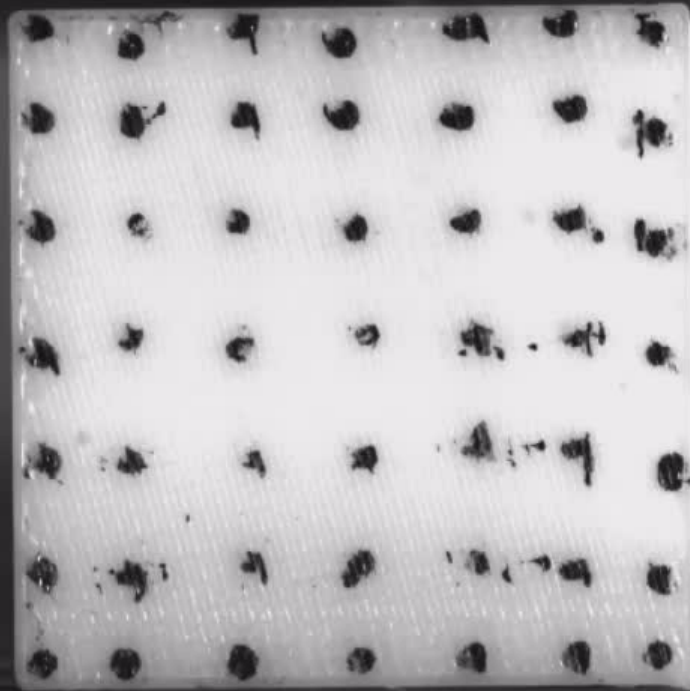
Mechanical response in additive manufacturing

ABS30



Mechanical response in additive manufacturing

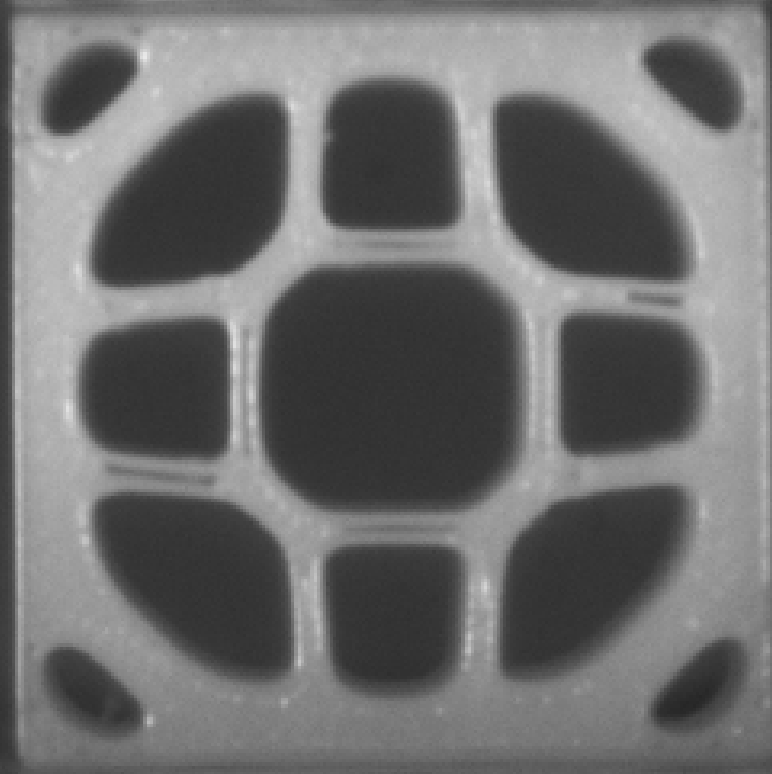
ABS00



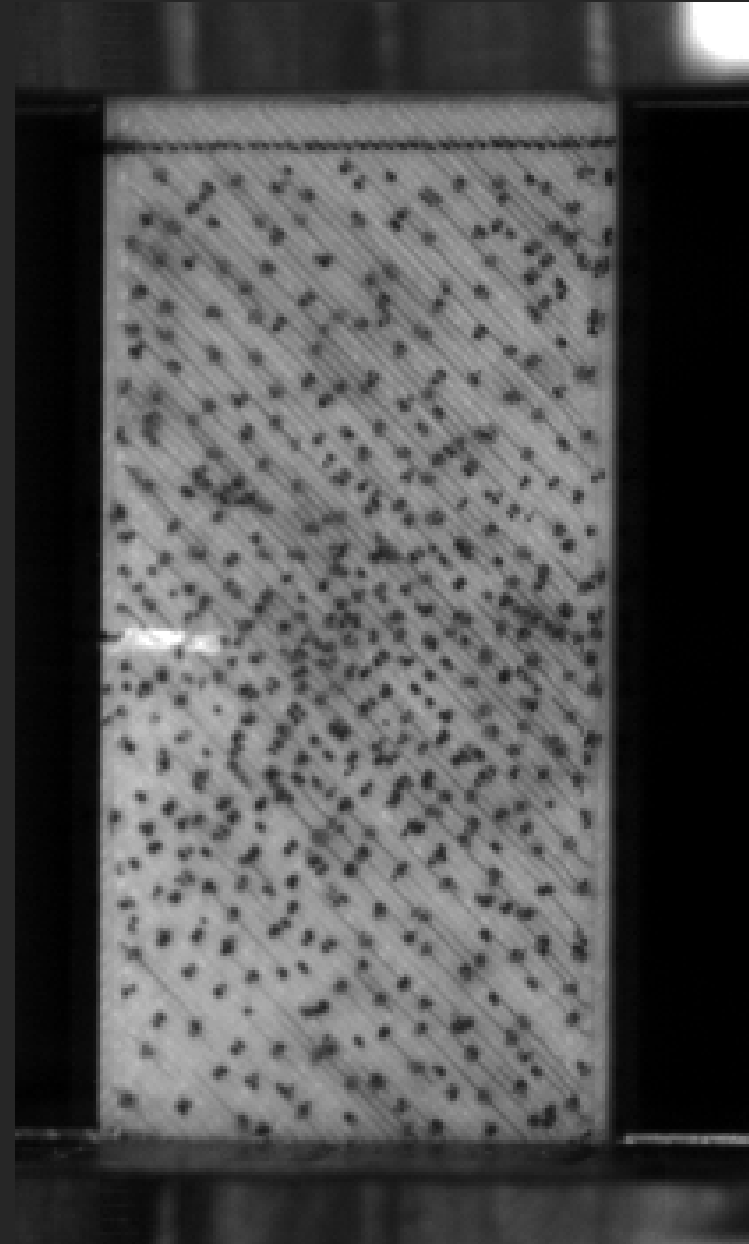
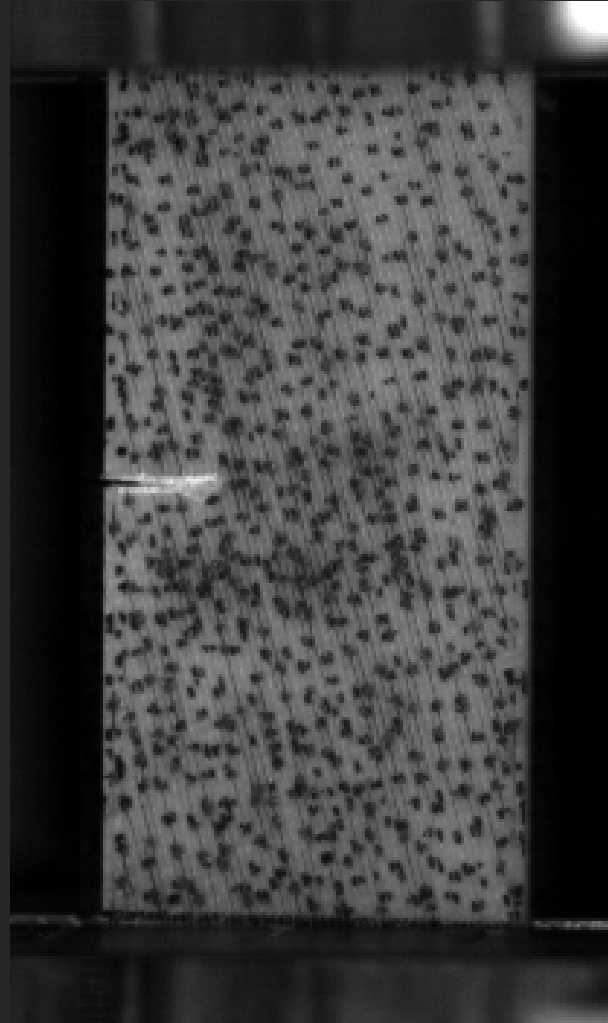
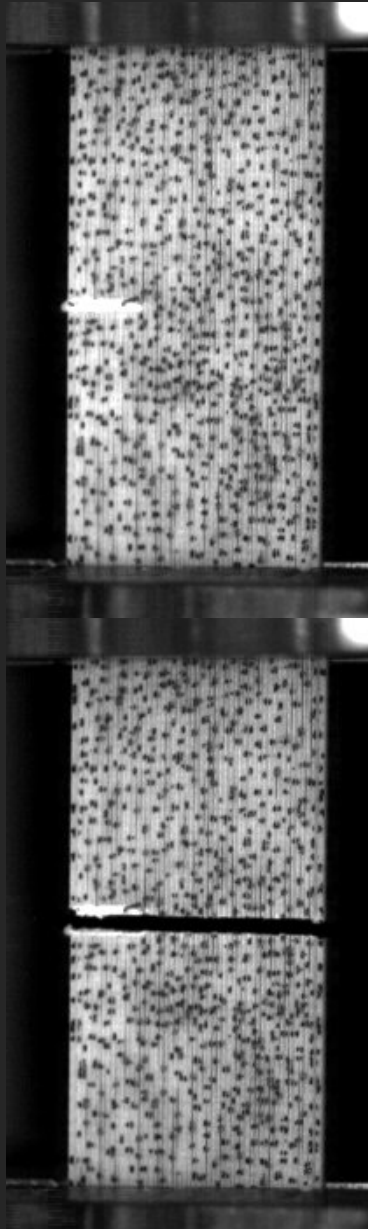
0.00 %

Mechanical response in additive manufacturing

0.00 % P1S2R1

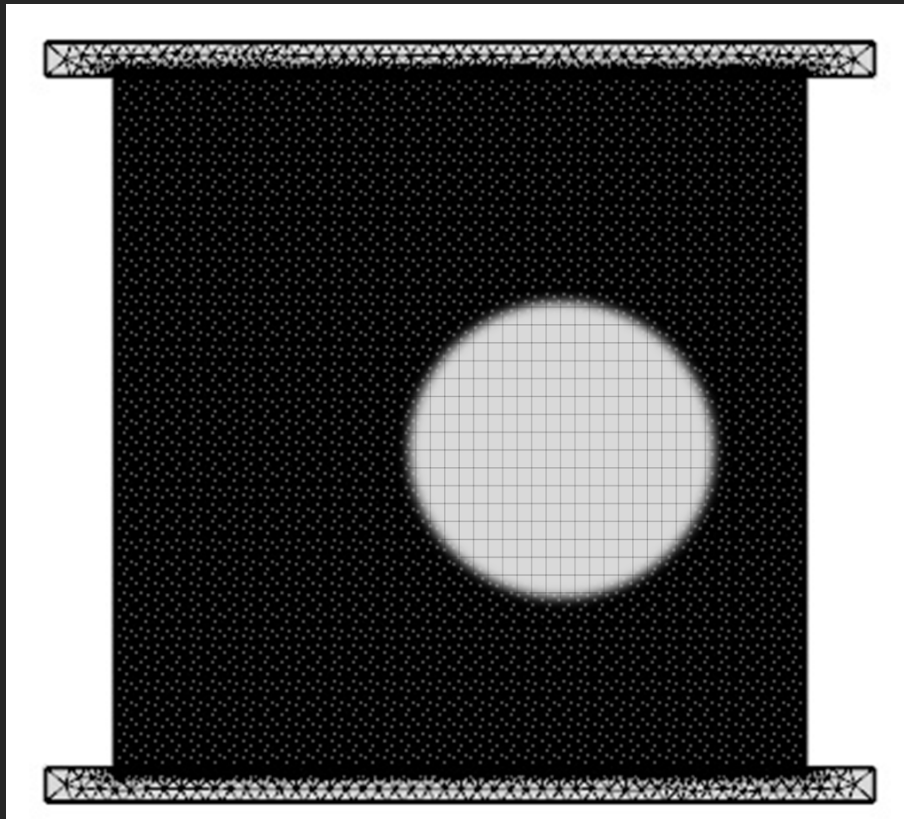


Mechanical response in additive manufacturing



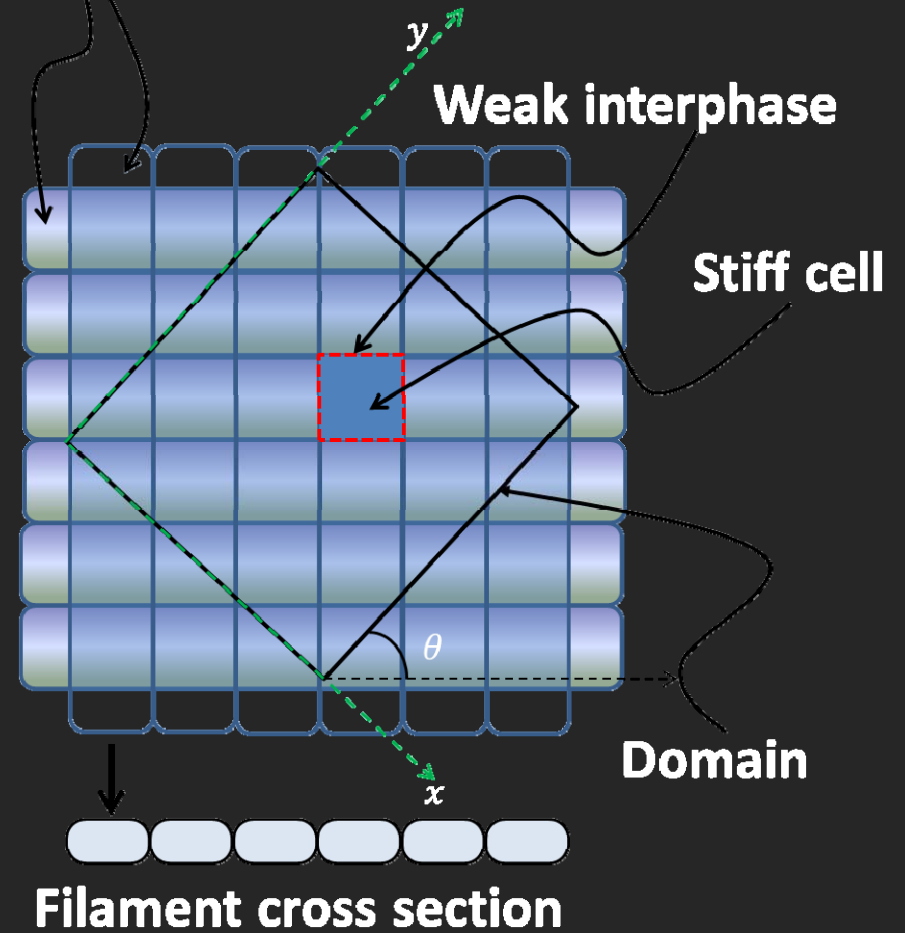
Comsol model:

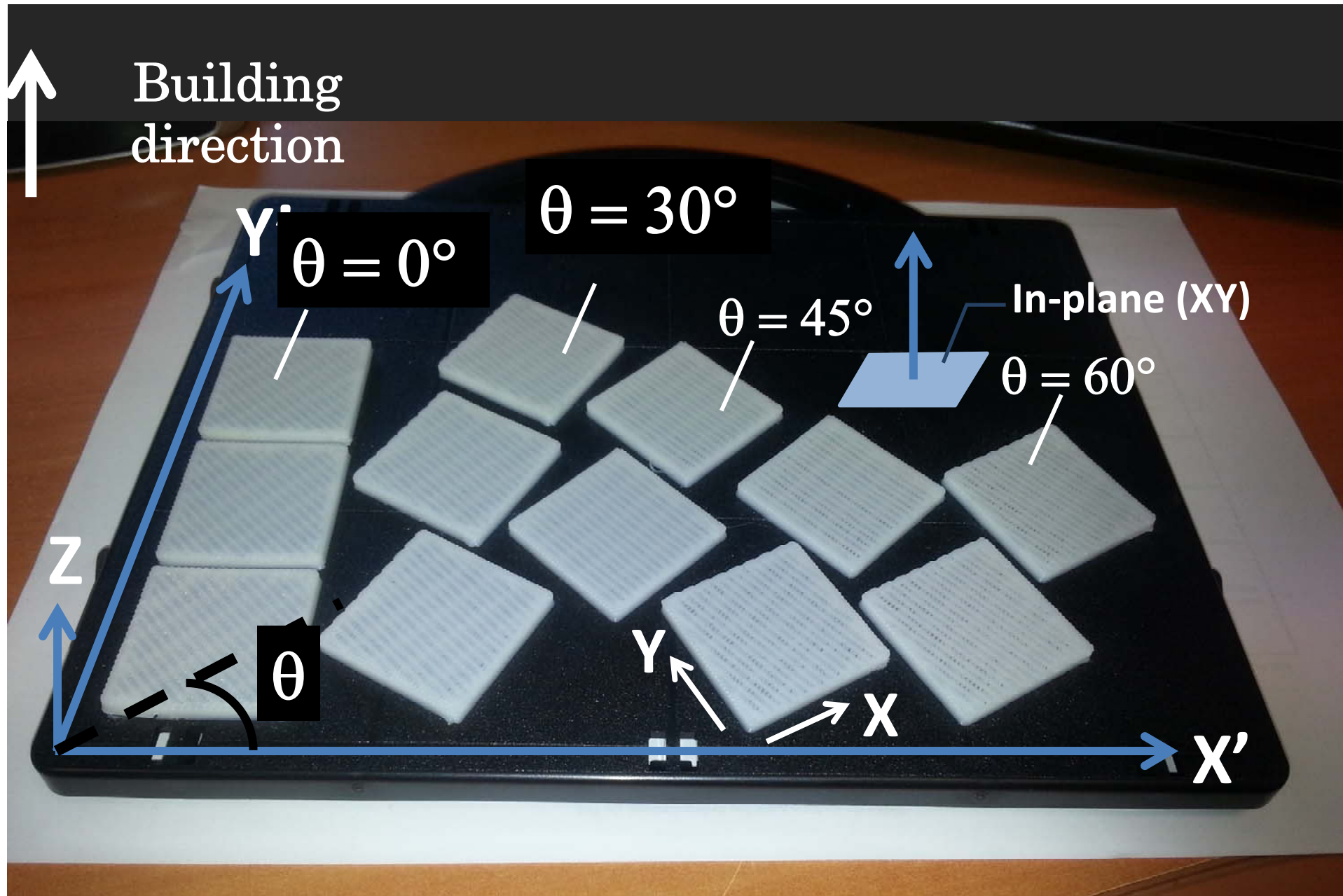
Handelling raster effect filament crossing sequence $+45^\circ/-45^\circ$



Regular meshing (2.7 M dof)

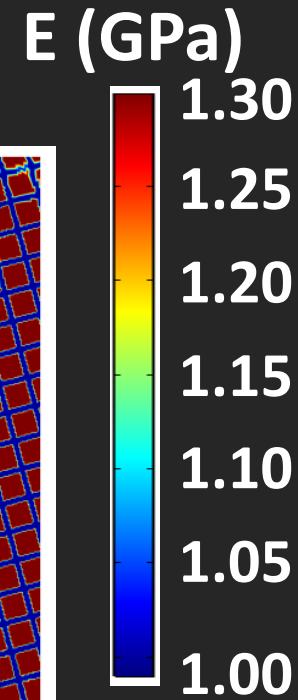
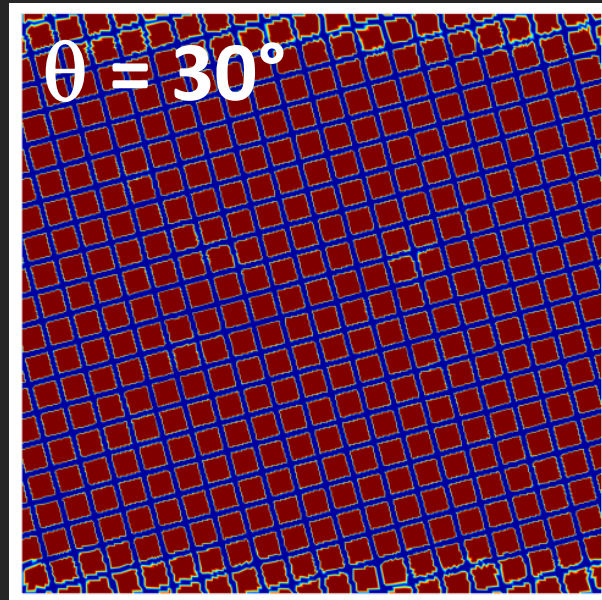
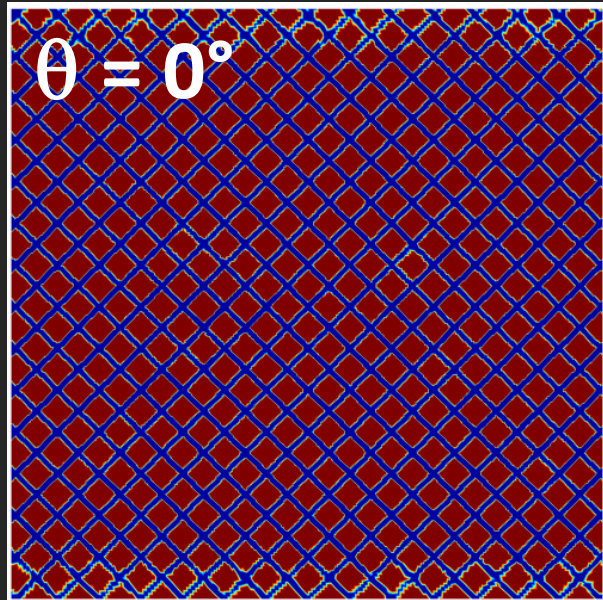
Crossed filaments





Fused Deposition modelling: printing angle

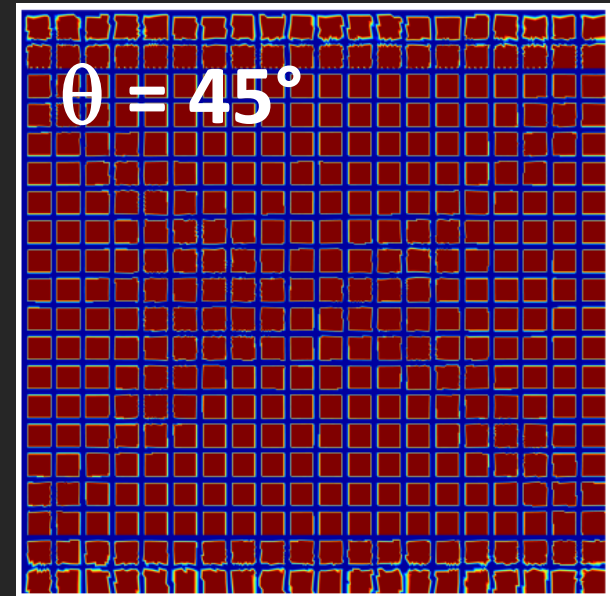
Local property distribution



Topological law: Young's modulus

$$E(m(x, y)) = \begin{cases} E_1 = E_{ABS} & \text{if } m \notin \partial\Gamma \\ E_2 = \alpha \times E_{ABS} \times D(\epsilon_i) & \text{if } m \in \partial\Gamma \end{cases}$$

$$D = 1 - \frac{\beta}{1 + e^{-\gamma(\epsilon_i - \epsilon_0)}}$$



Compression
behaviour

Heterogeneous strain
field

Positive strain
Poisson's
expansion

Crack opening
(mixed mode)

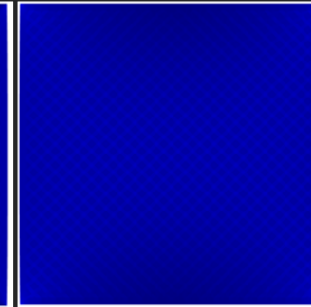
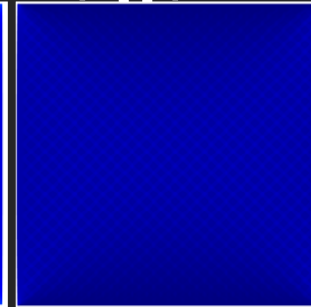
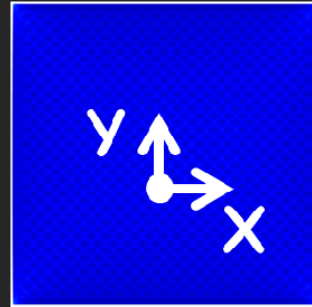
Load

ϵ_{xx} (%)

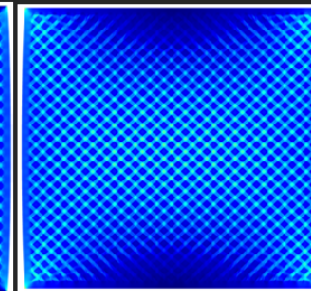
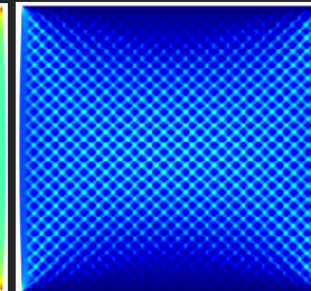
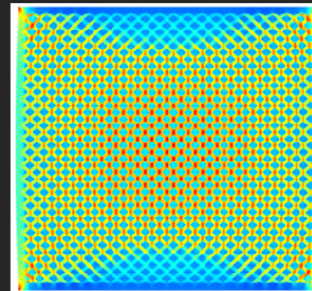
$|\epsilon_{yy}|$ (%)

ϵ_l (%)

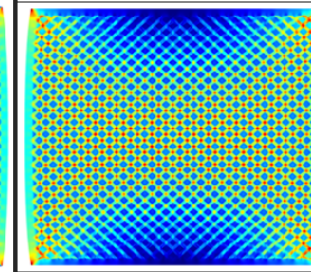
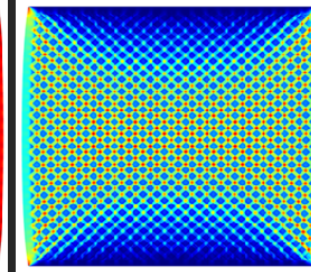
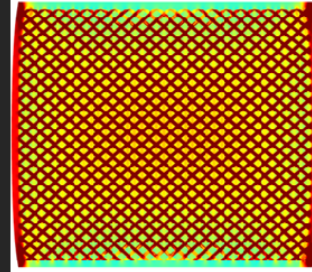
1%



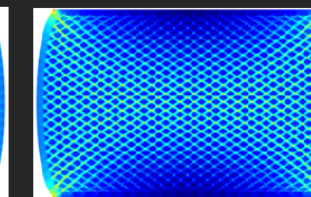
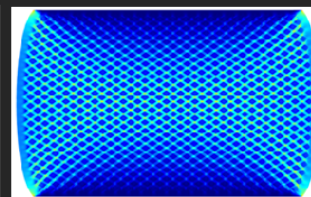
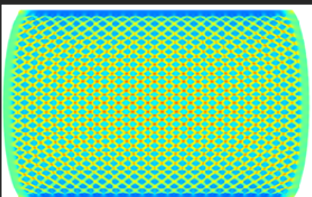
5%



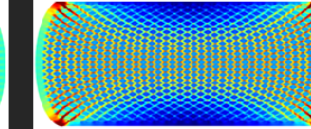
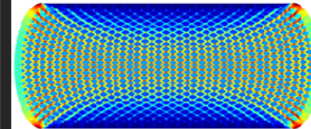
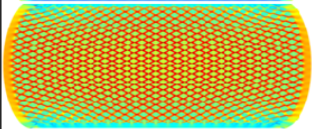
9%



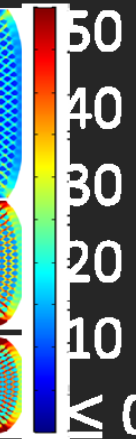
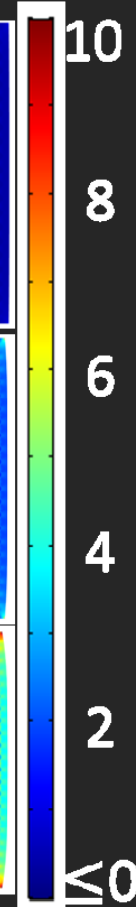
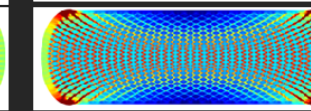
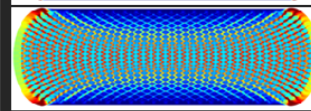
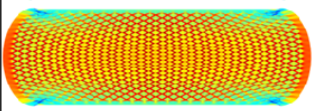
30%



50%

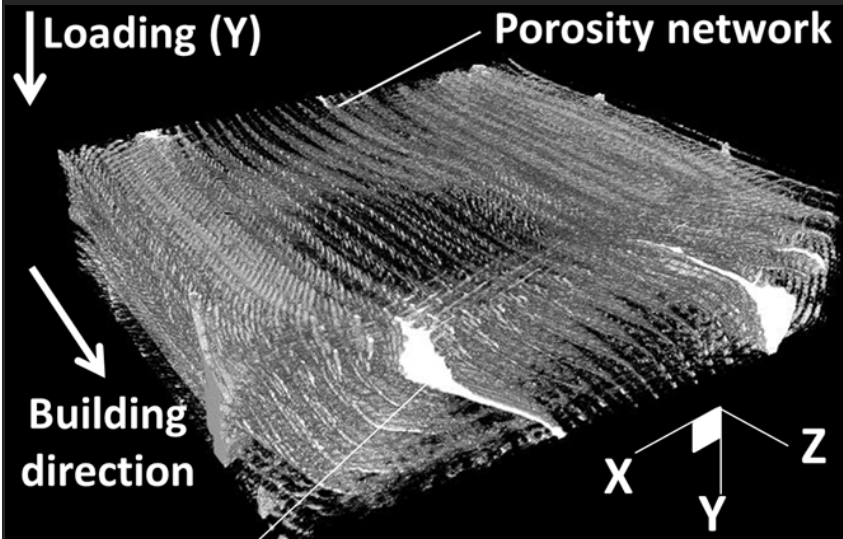
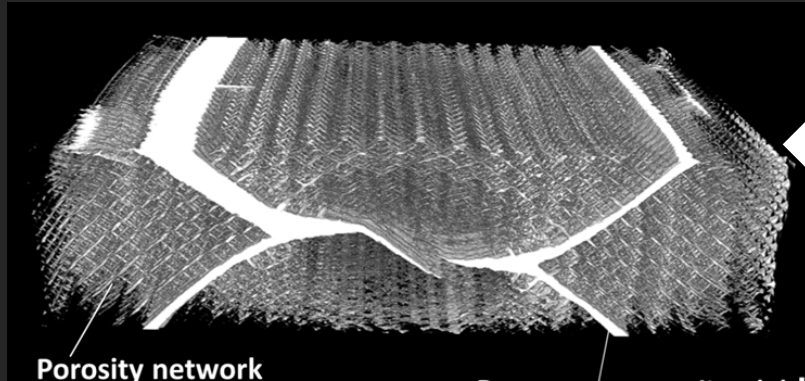


60%



Explaining effect of raster on performance

3D imaging



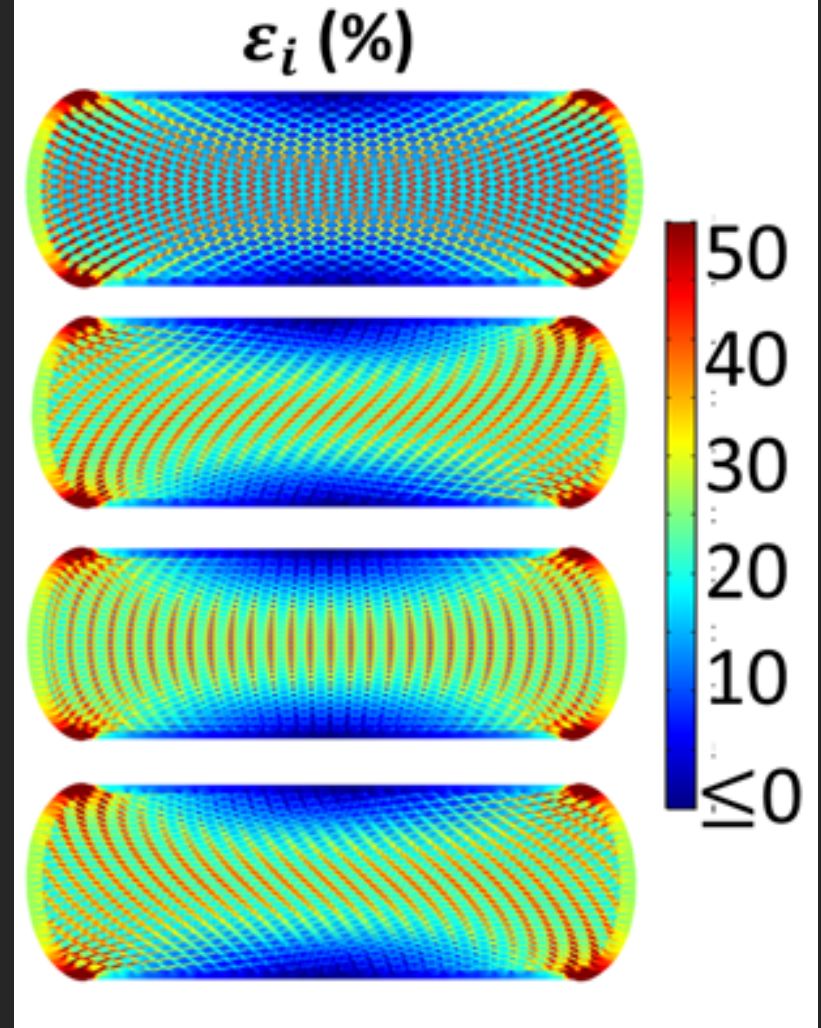
θ ($^{\circ}$)

0

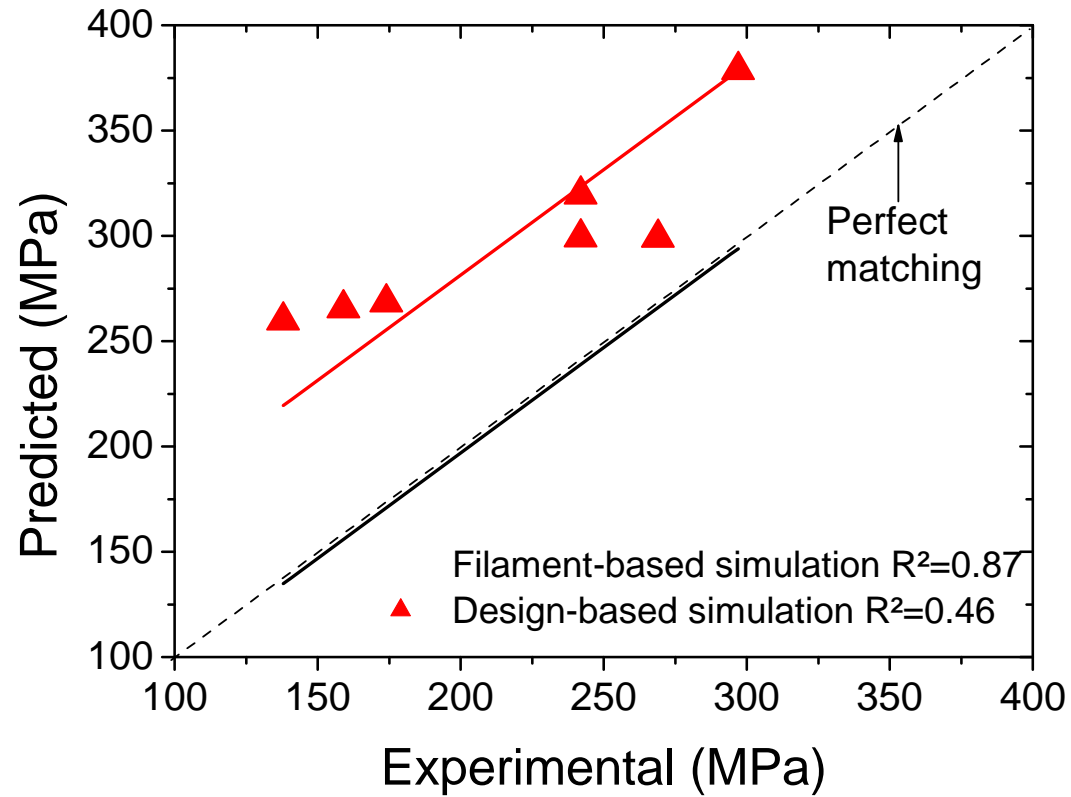
30

45

60



Comsol predictions

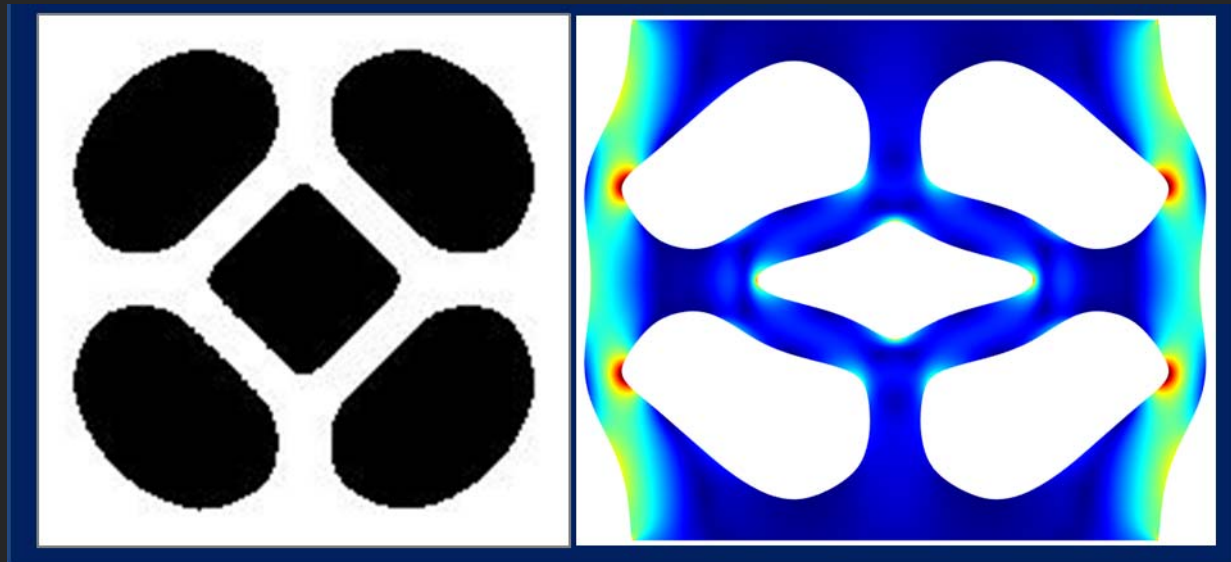


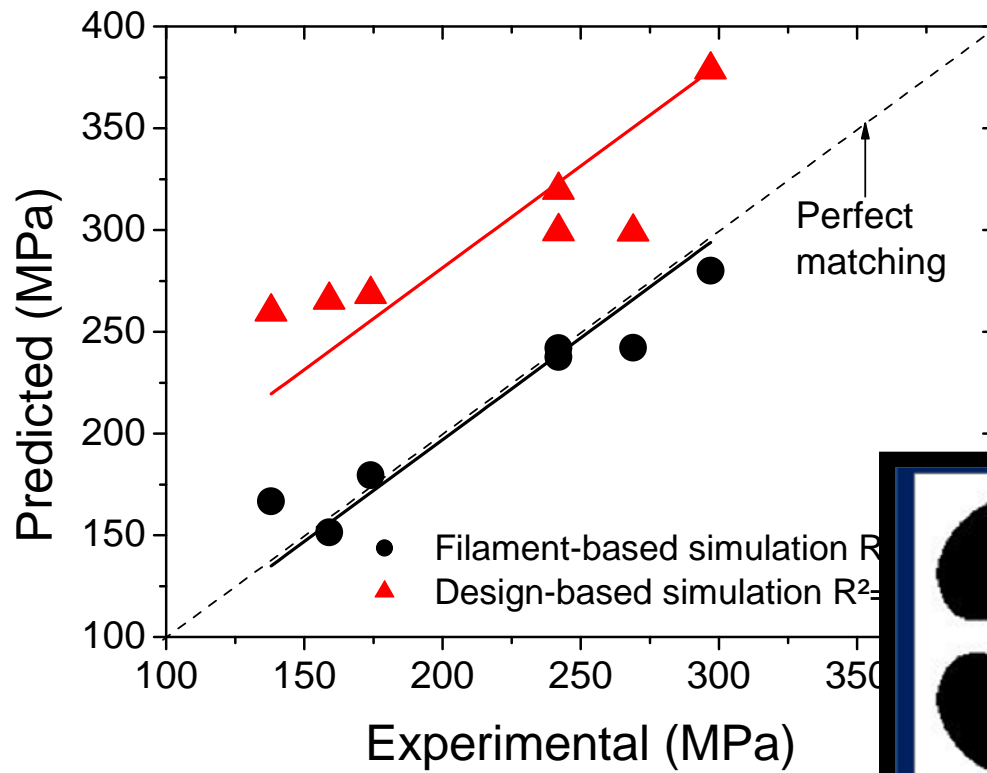
CAD-based
modelling:
Compression
performance of
cellular
structures

Strain field

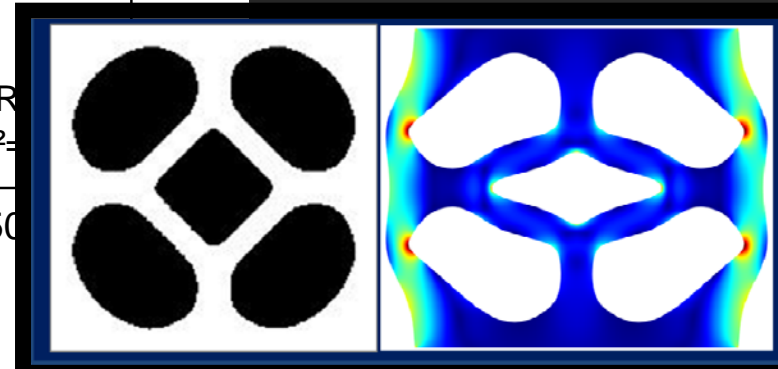


Comparison
between FE and
experimental
Young's moduli

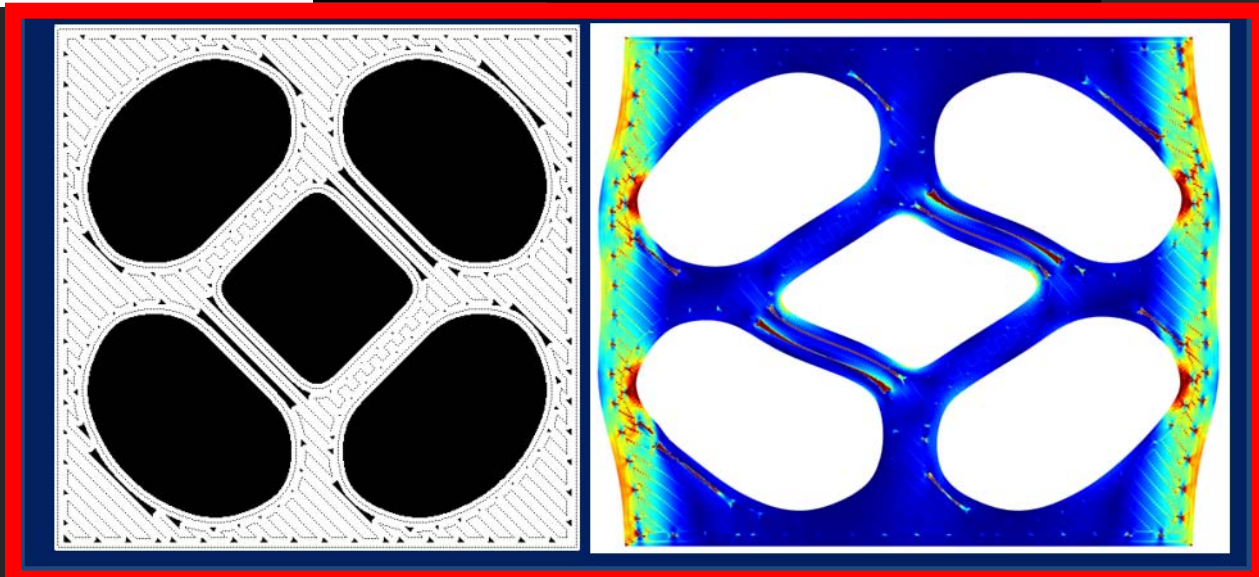




Filament-based
modelling: Best
fit to
experimental
conditions

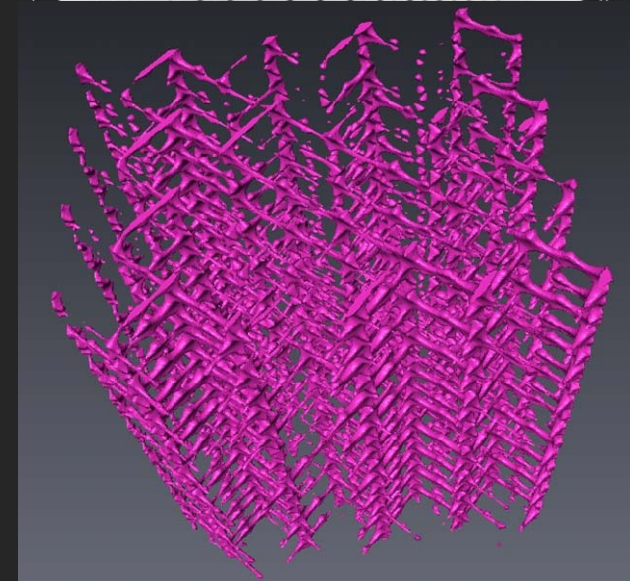
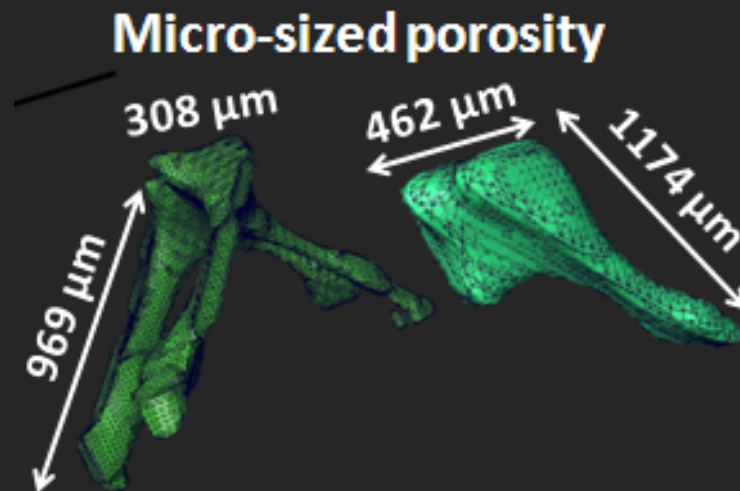
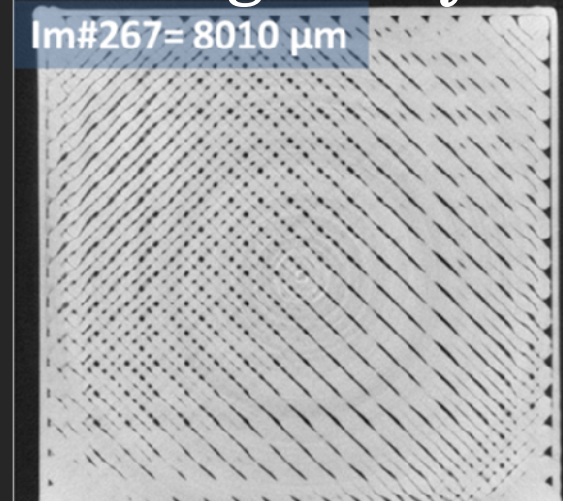
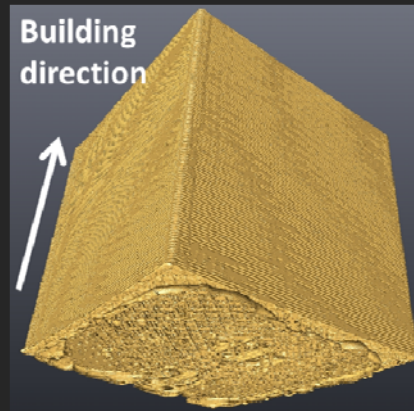
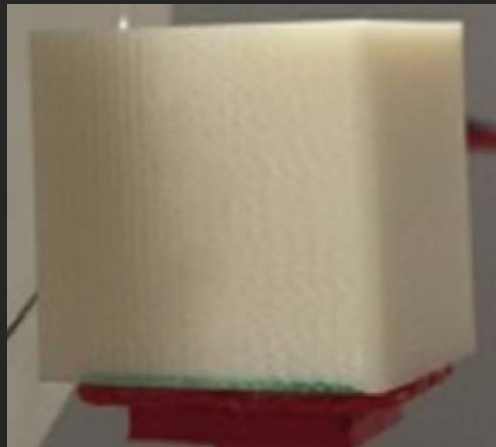


Heterogeneous
strain field based
on implementation
of Filament-
trajectory



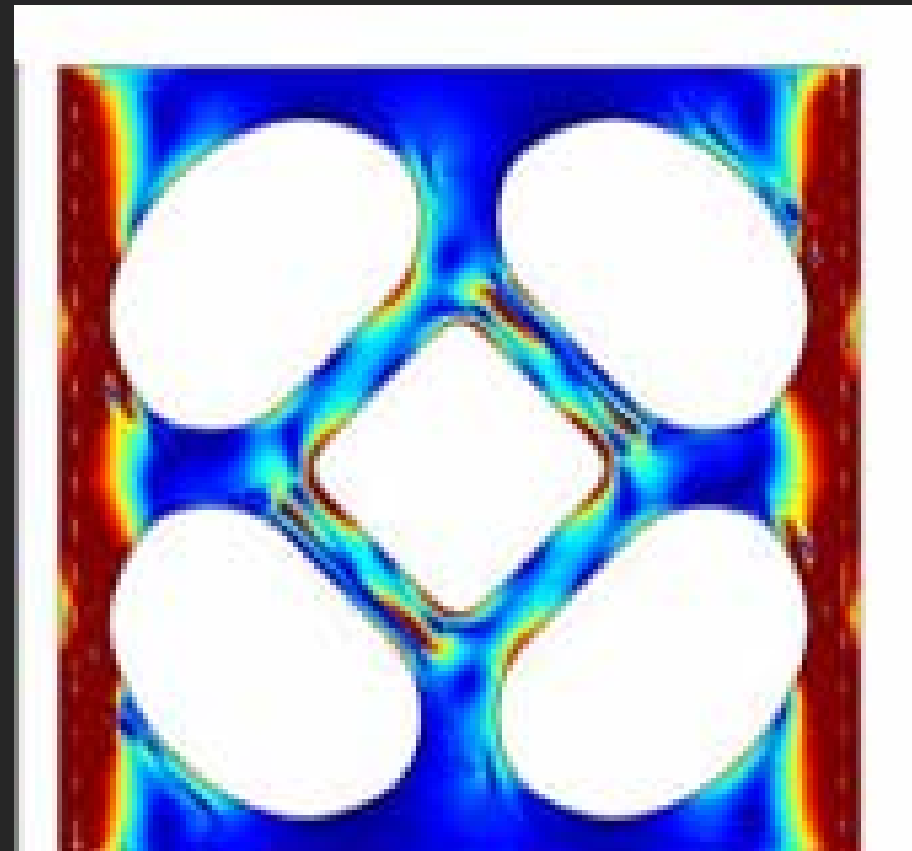
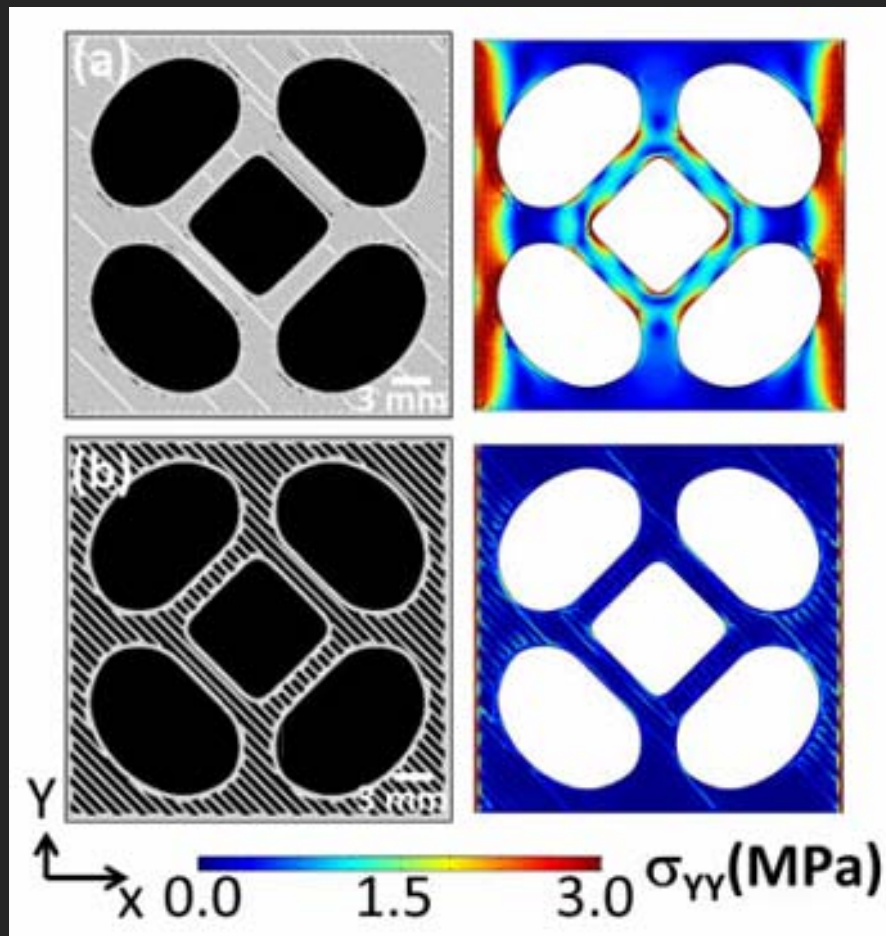
Conclusions

- Relevant scale for FE modelling in additive manufacturing : microstructural heterogeneity



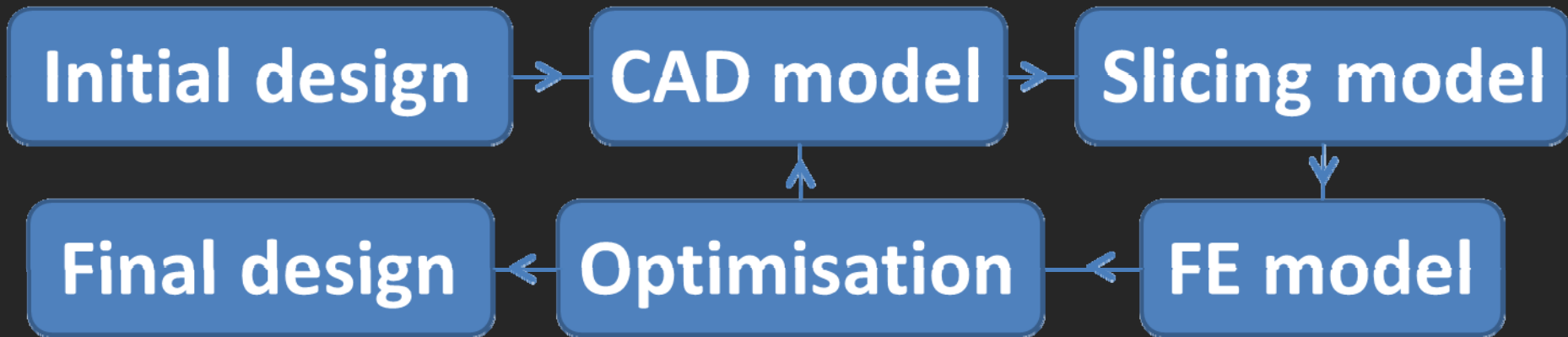
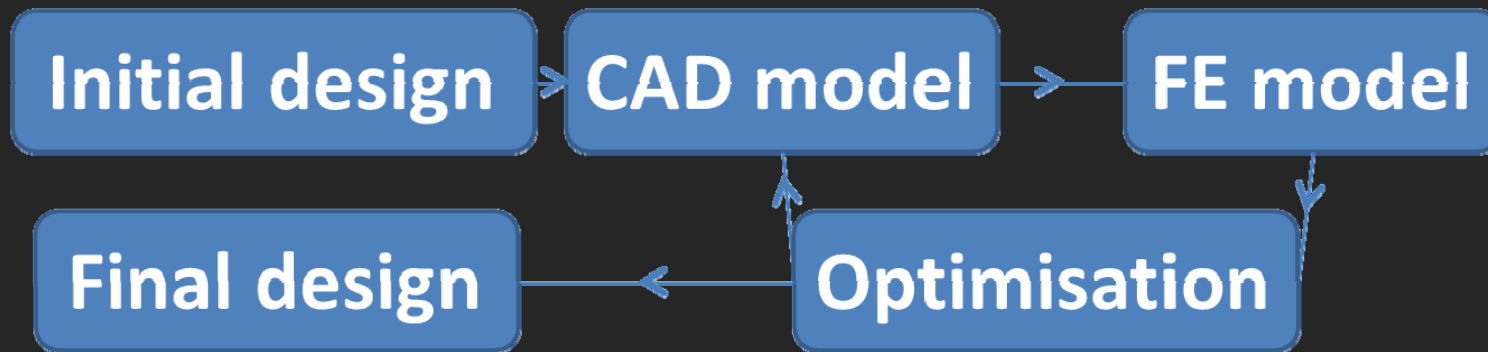
Conclusions

- Filament-based FE simulation: lack of cohesion between filament + process-induced porosity



Conclusions

- Unrealistic predictions from CAD-based models



Conclusions

- ❑ Complex deformation mechanisms guided by process conditions (printing angle)

