COMSOL CONFERENCE 2018 LAUSANNE

COMSOL MULTIPHYSICS®

Modeling of pound cake baking behavior in continuous flow

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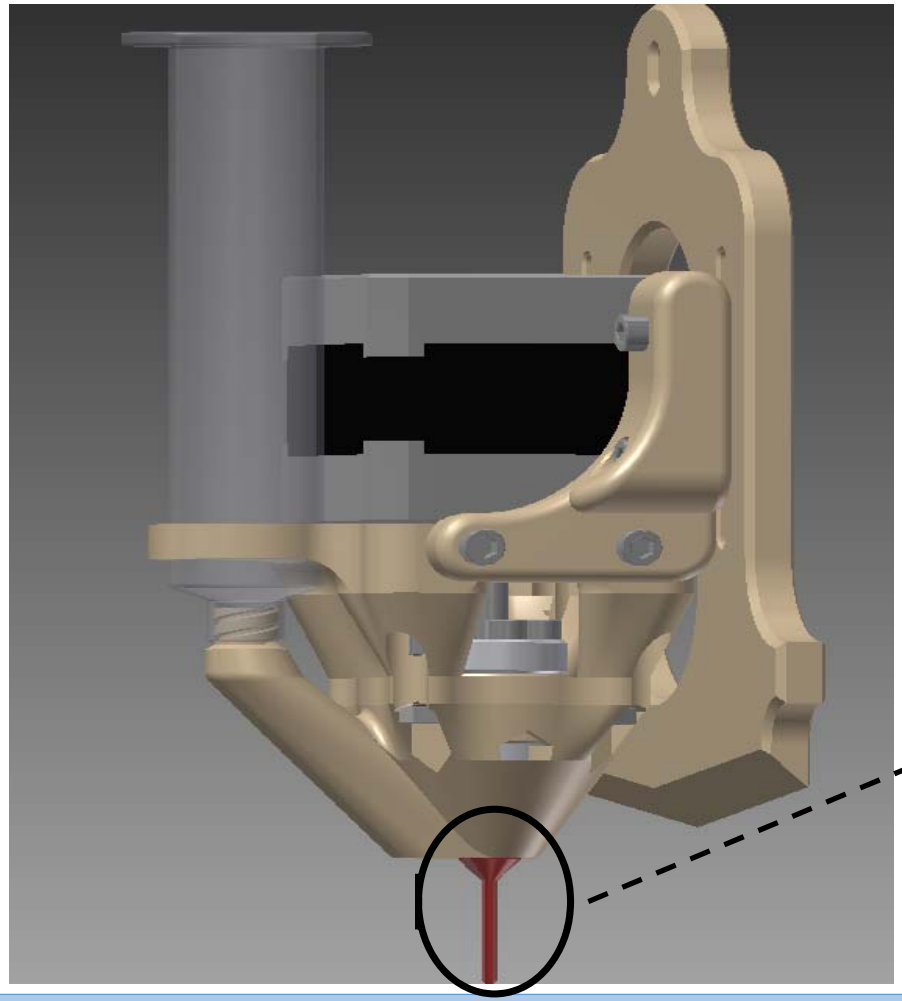
Food for Tomorrow | Cap Aliment
Recherche, Formation & Innovation en PAYS de la LOIRE

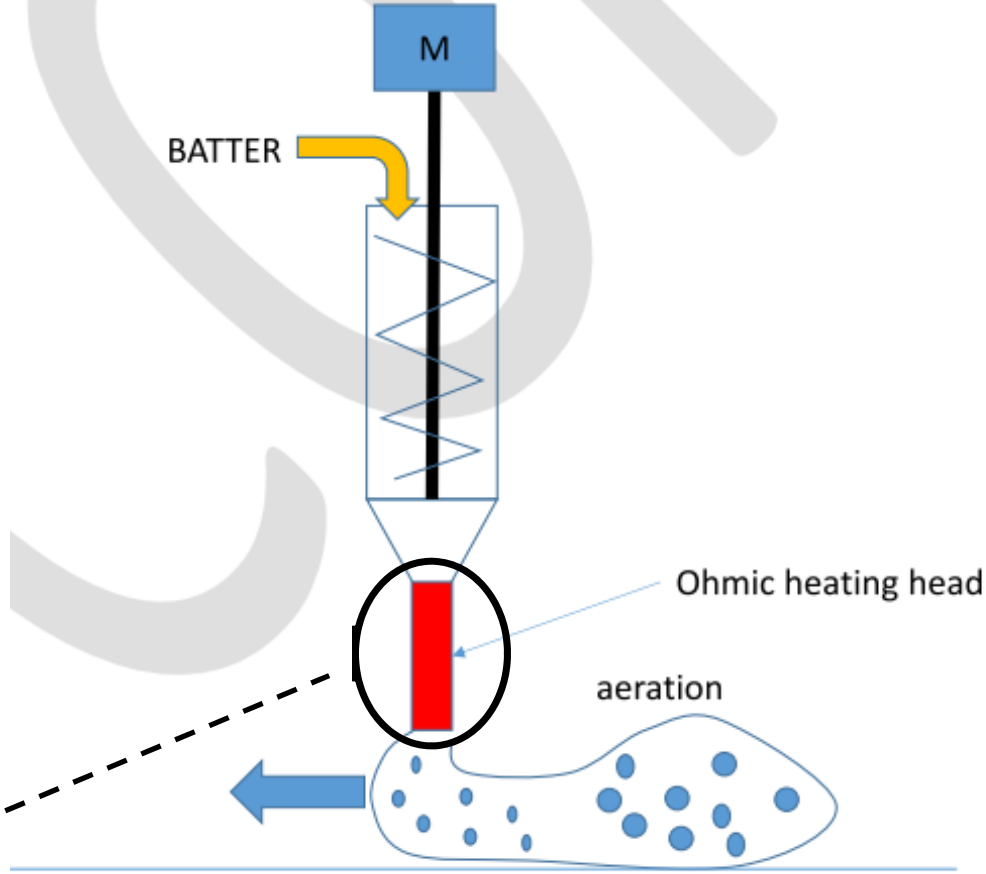
INRA SCIENCE & IMPACT

Oniris École Nationale Vétérinaire, Agroalimentaire et de l'Alimentation

UNION EUROPÉENNE
Région PAYS de la LOIRE
CE PROJET EST COFINANCÉ PAR LE FONDS EUROPÉEN DE DÉVELOPPEMENT RÉGIONAL

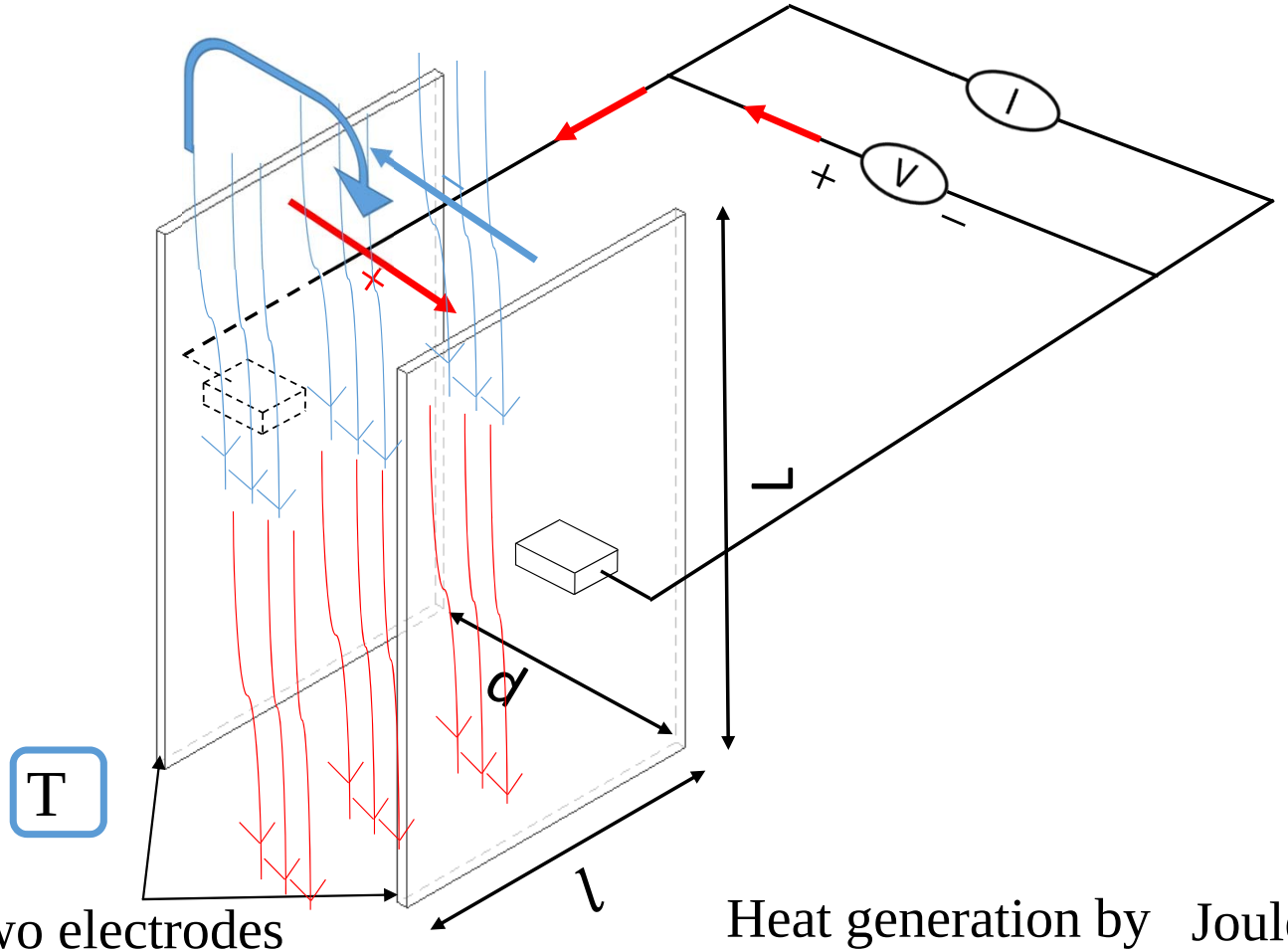
3D Printer Head





What is OH ?

Fluid flow



T

Two electrodes

Input:
Constant Votlage V
Variable Current I

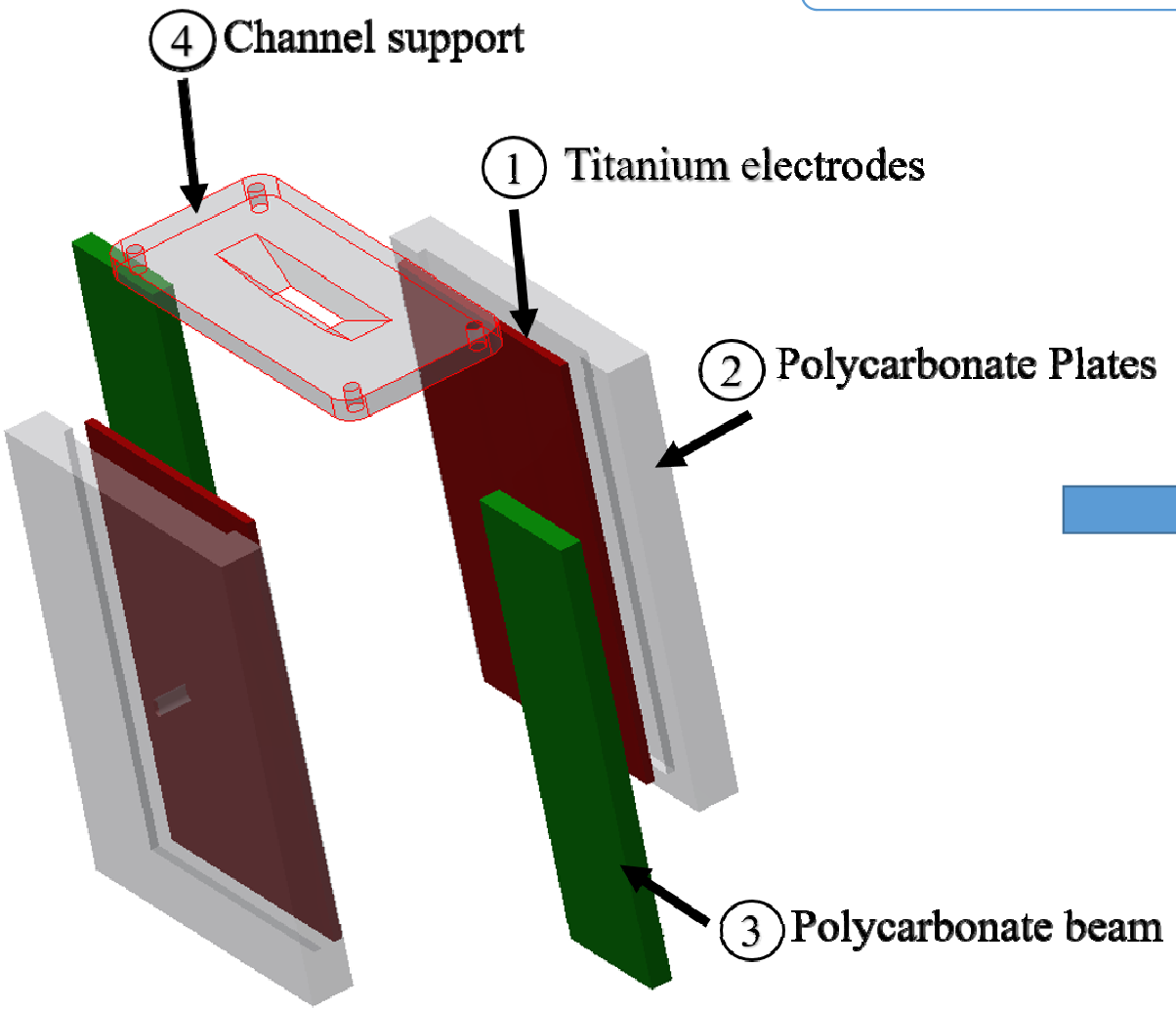
$S_{electrodes} = L * l$

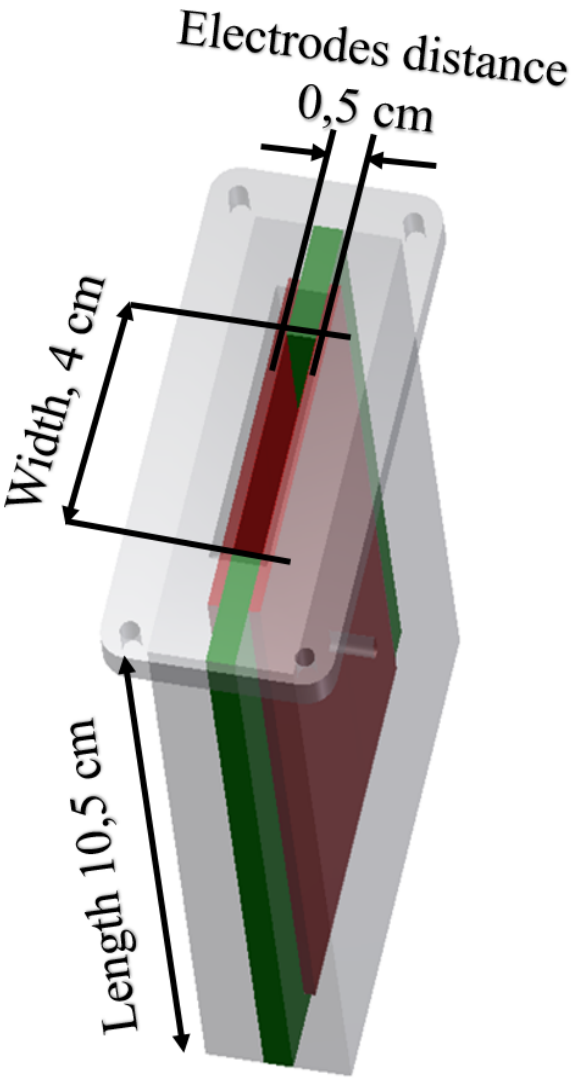
Field strengh: $E = \frac{V}{d}$

Electrical conductivity: $\boldsymbol{\sigma}$

Heat generation by Joule effect: $\dot{Q} = \sigma |E|^2$

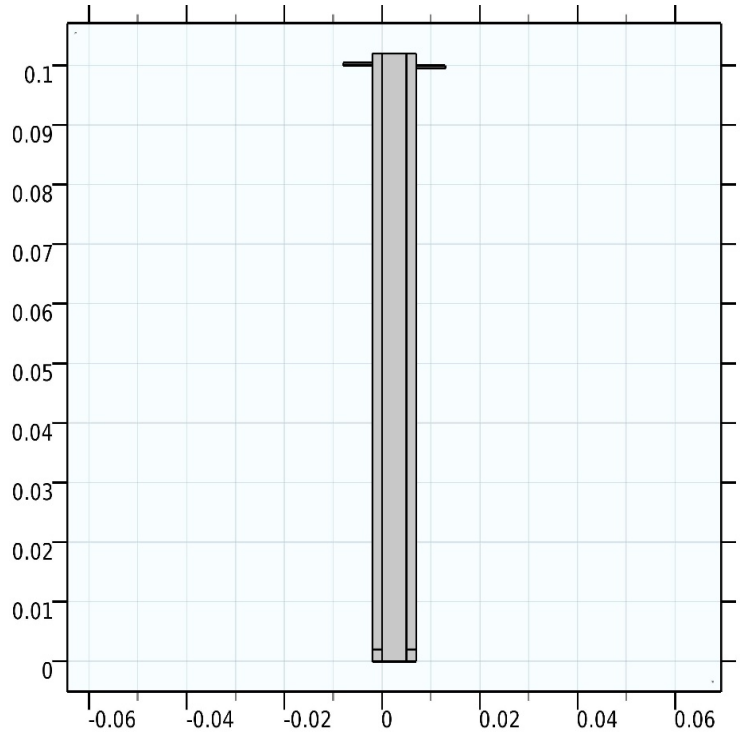
Nozzle Geometry

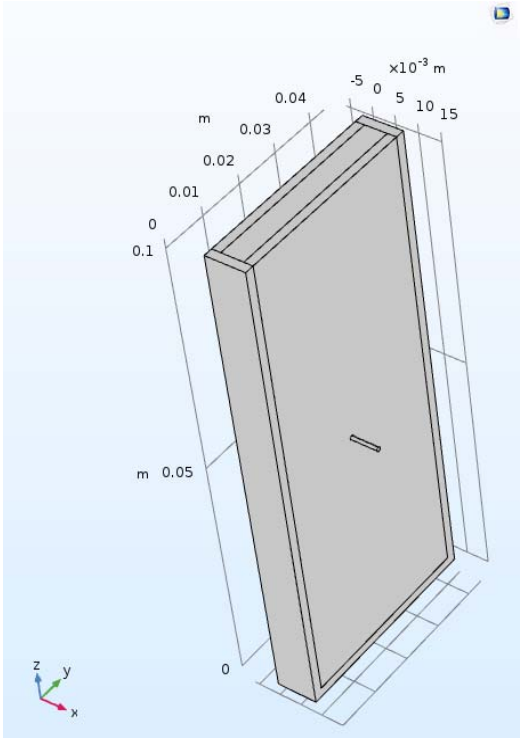




COMSOL Geometry and Physics ?

2D and 3D models were plotted on COMSOL 5,3a.



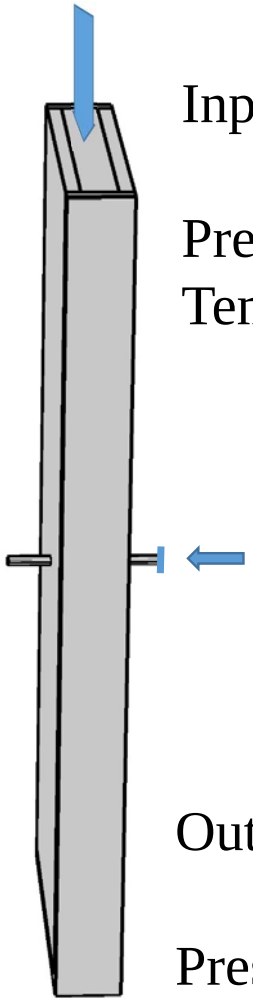


1. Laminar flow ➡ Paste

2. Joule effect heating ➡
Ohmic heating

Coupled with
3. Heat transfer in solids

Boundary conditions



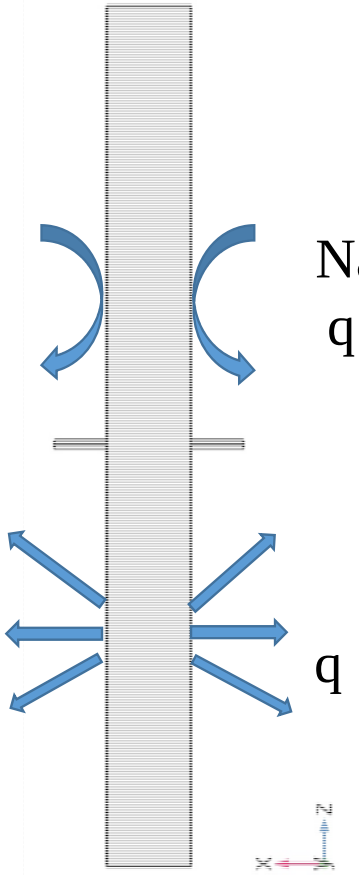
Input conditions

Pressure = 6 atm
Temperature = 20 °C

Heat Source
V = 75V

Output conditions

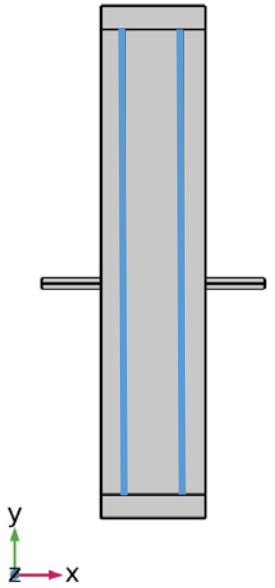
Pressure = 1 atm
Temperature = T



Front view

Natural convection
q = h ($T_{amb} - T$)

Radiation
q = ε ($T_{amb}^4 - T^4$)



No slip
u = 0

Top view

Navier stockes

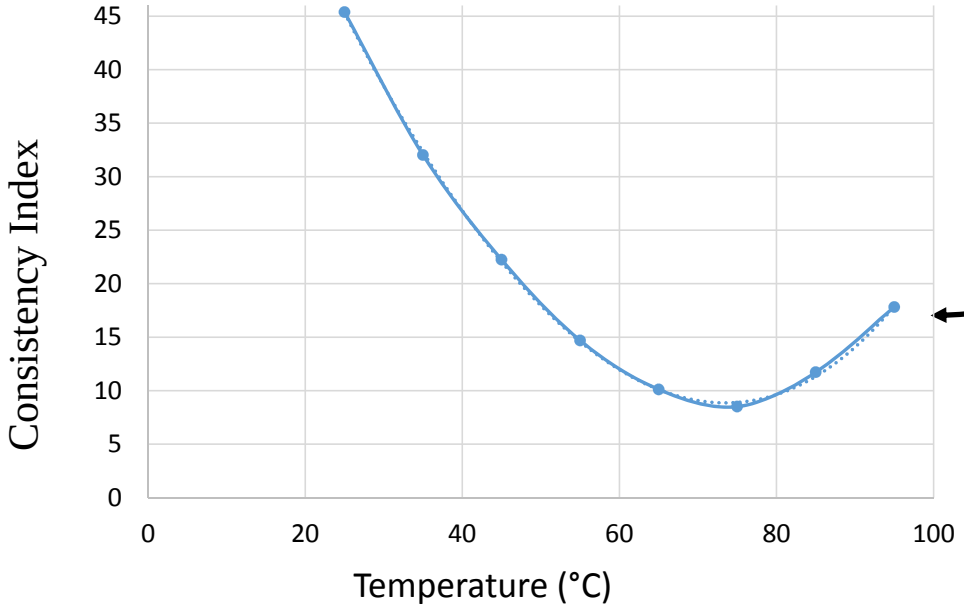
$$\rho \frac{\partial u}{\partial t} - \nabla . \eta(\dot{\gamma})(\nabla u + (\nabla u)^T) + \rho u . \nabla u + \nabla p = 0$$

Dynamic Viscosity
Power law equation:

$$\eta = m \dot{\gamma}^{n-1}$$

Flow index
n =0,624

Consistency Index (m)



Navier stockes

$$\rho \frac{\partial u}{\partial t} - \nabla . \eta(\dot{\gamma})(\nabla u + (\nabla u)^T) + \rho u . \nabla u + \nabla p = 0$$

Dynamic Viscosity
Power law equation:

$$\eta = m\dot{\gamma}^{n\ -1}$$

Shear rate which is temperature dependant

➡ The model uses the shear rate calculated by COMSOL to determine the viscosity variation in function of temperature and shear rate.

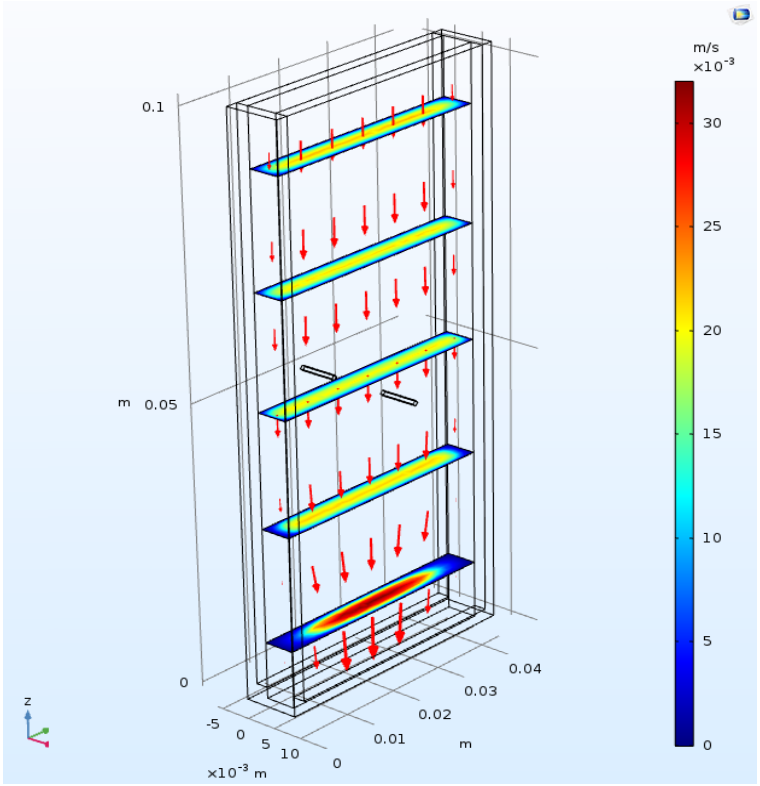
Thermal diffusion equation

Heat transfer

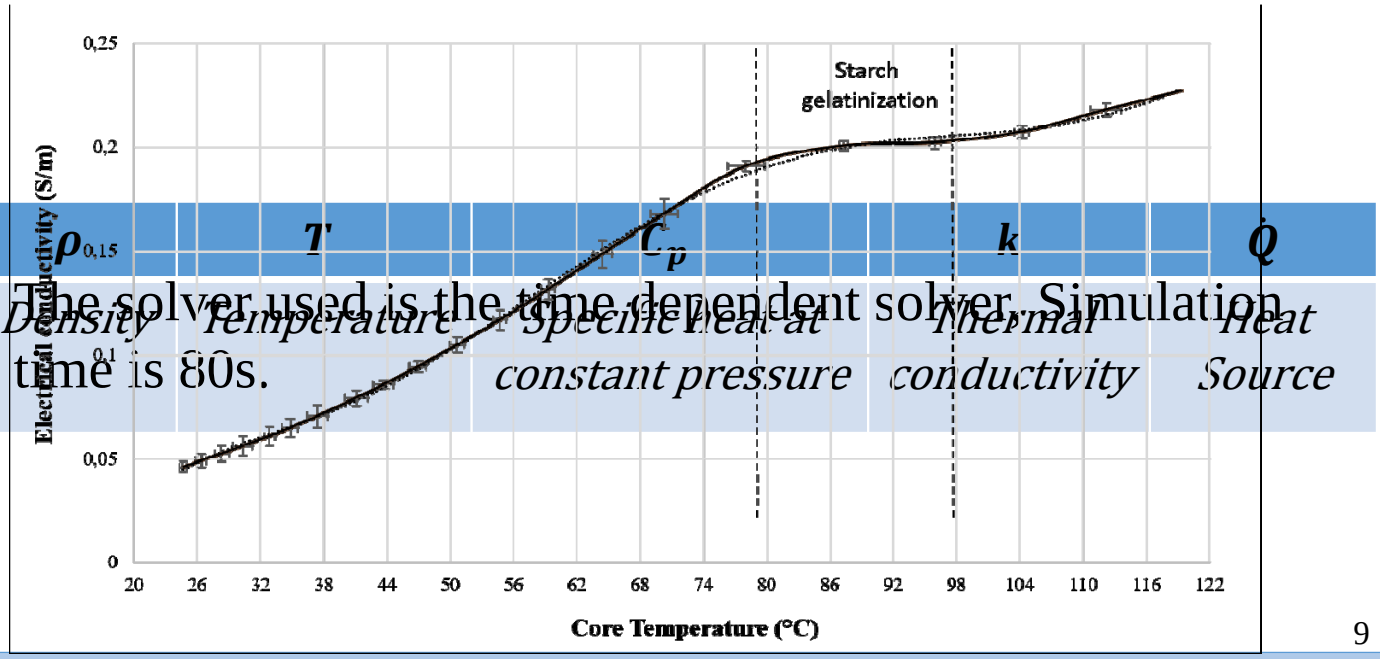
$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p \mathrm{u}.\nabla T = \nabla.(k\nabla T) + \dot{Q}$$

Coupled with Joule effect

$$\dot{Q} = \sigma |E|^2$$



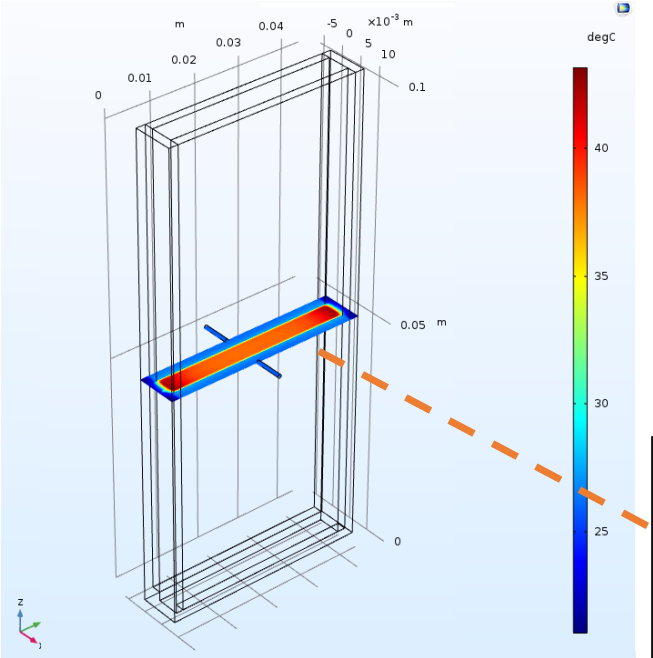
Navier stockes



ρ	T	C_p	k	$\dot{Q}$
Density	*Temperature*	*Specific heat at constant pressure*	*Thermal conductivity*	*Heat Source*

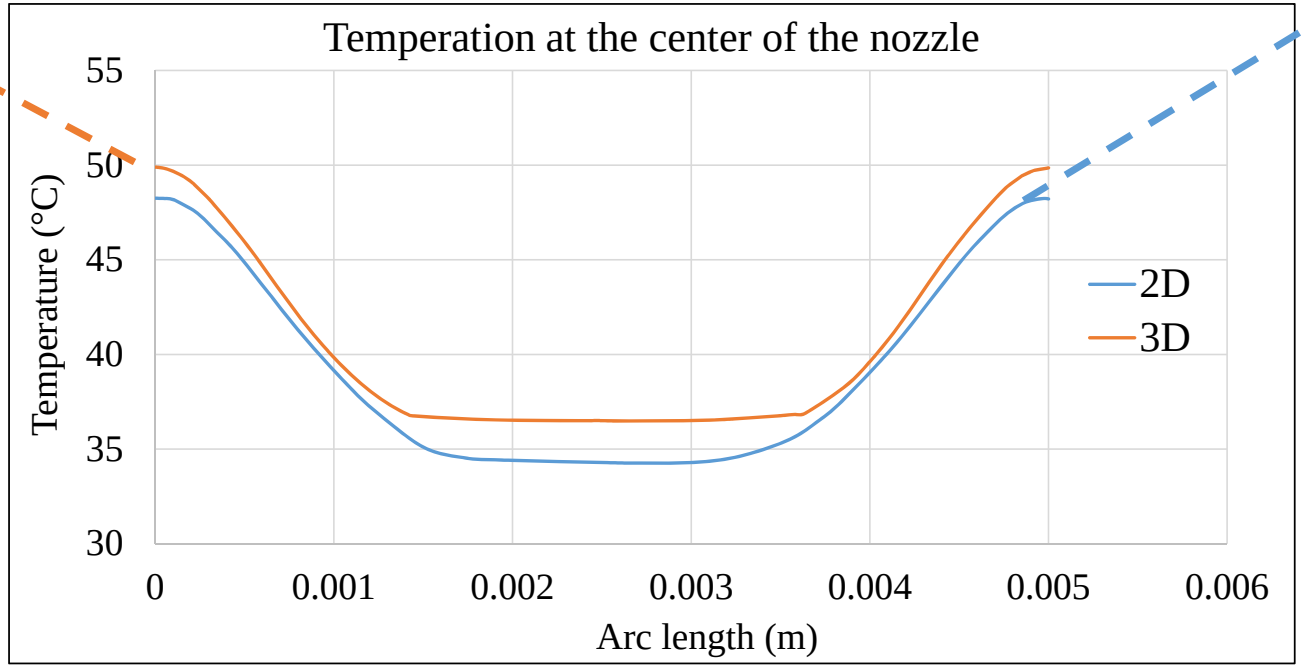
The solver used is the time dependent solver. Simulation time is 80s.

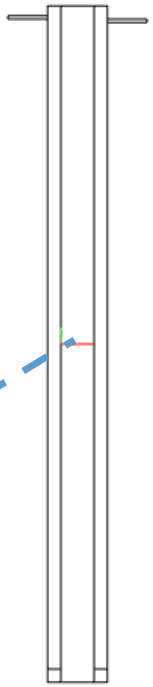
2D and 3D comparison



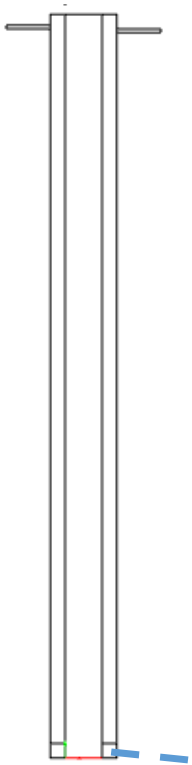
Temperature at the center

Difference $\approx 2°C$

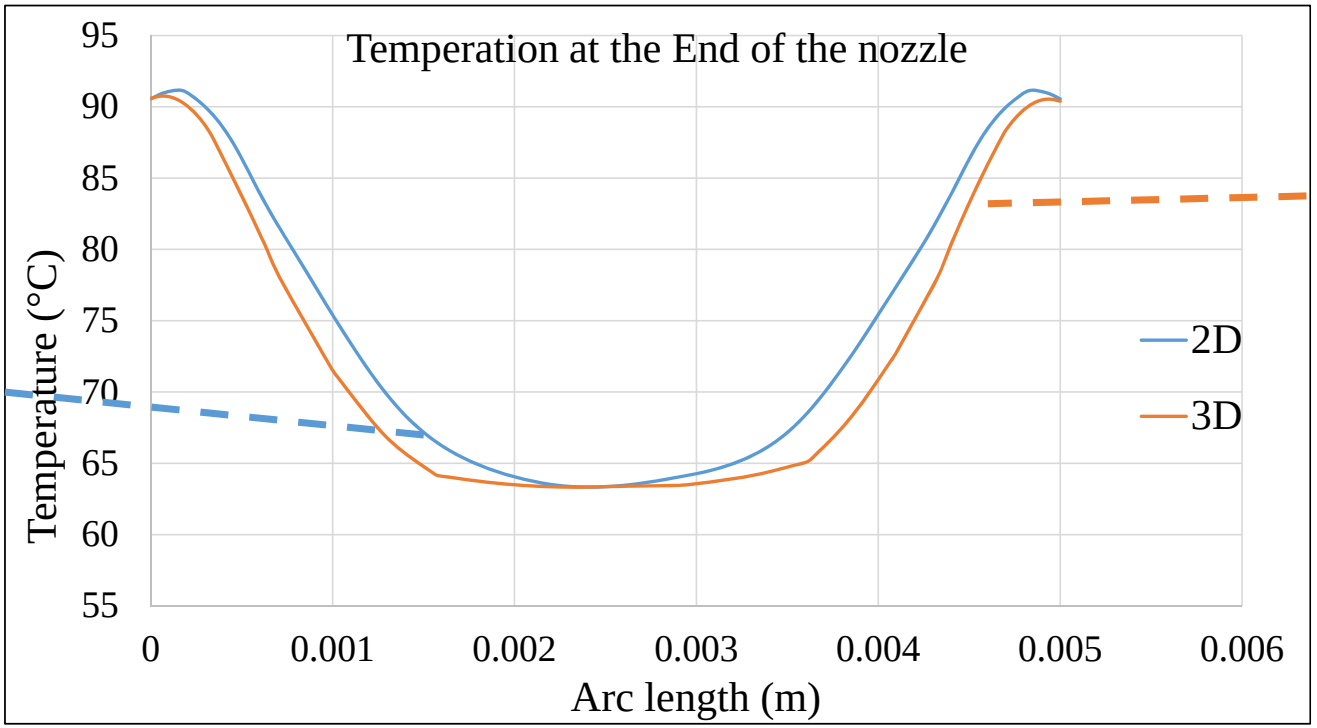


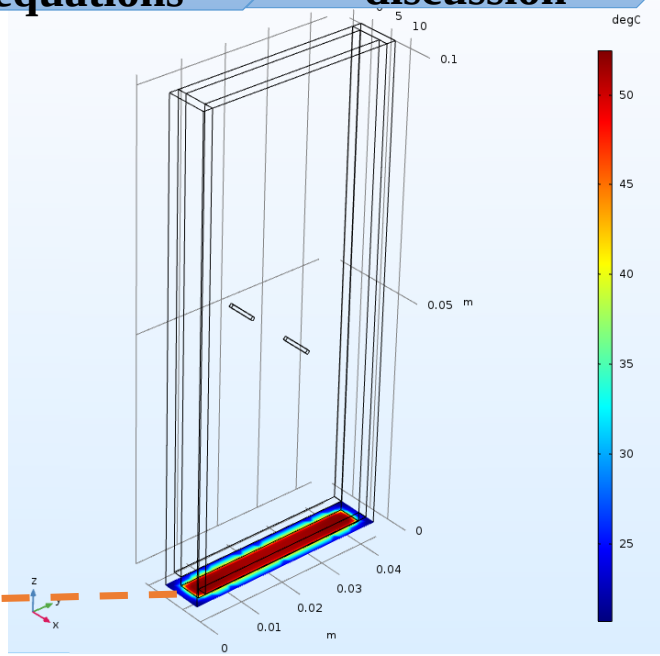


2D and 3D comparison

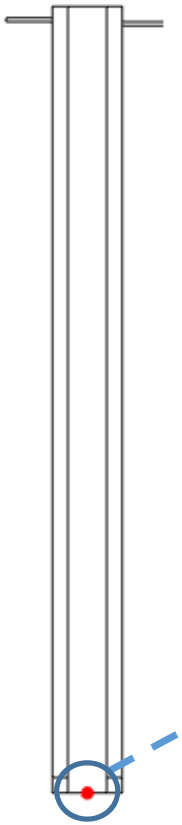


Temperature at the Output
Difference ≈ 1,5°C

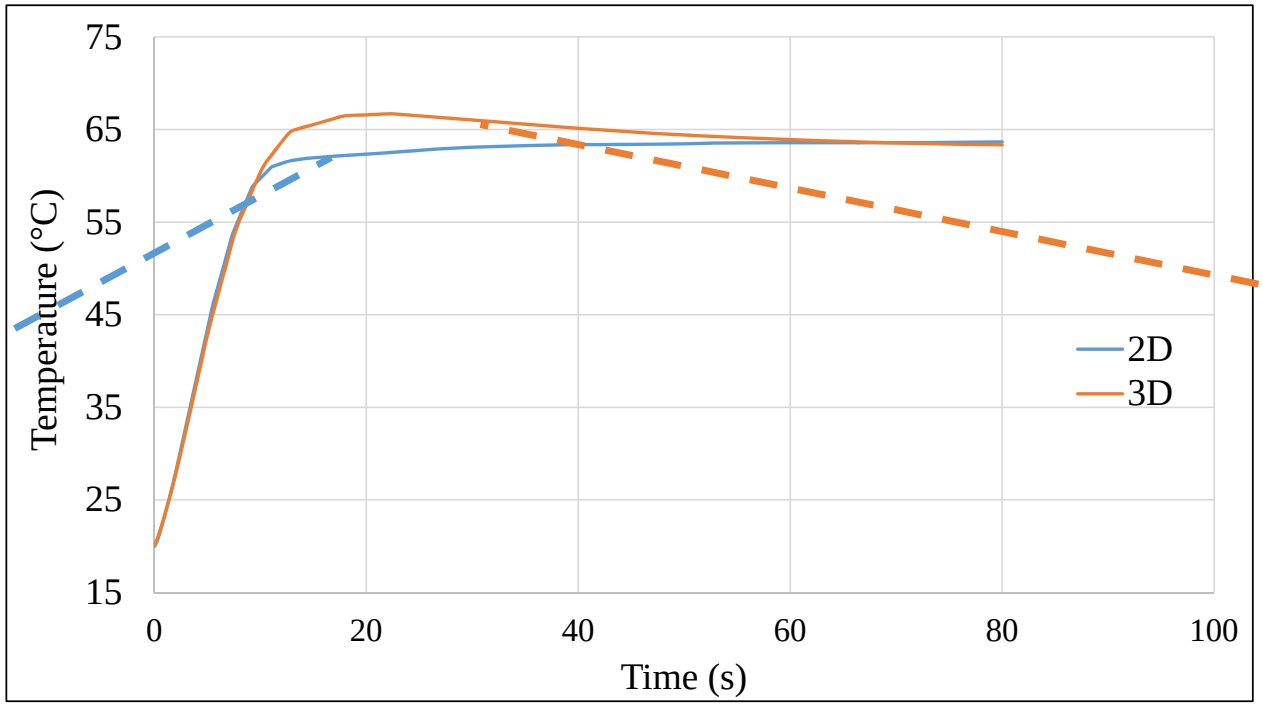


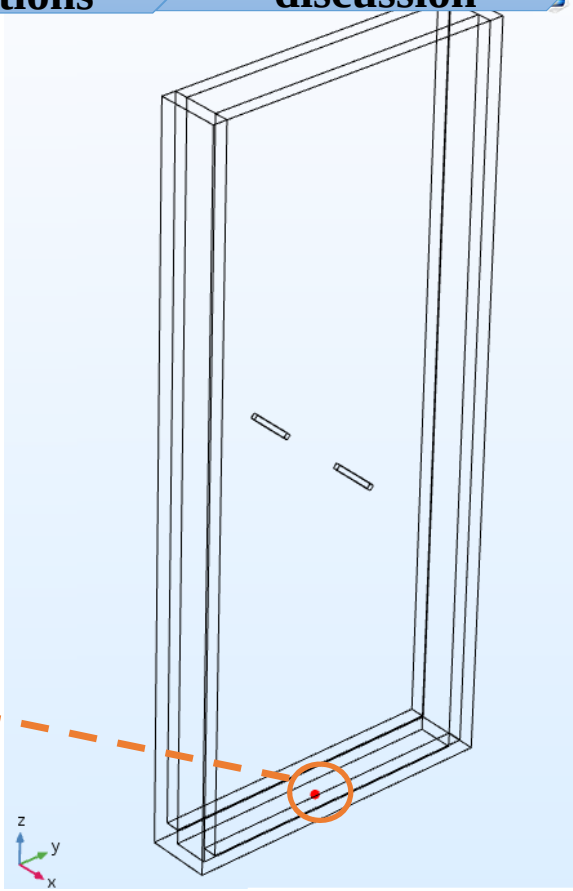


2D and 3D comparison



Temperature on a point at the End of the nozzle





Prameter sweep

Afficher

Label: Température (ht)

Données

Jeu de données: Etude 1/Solutions paramétriques 1 (sol2)

Valeur des paramètres (largeur_electrodes (m)): 0.02

Temps (s): 500

Titre

Type de titre: Aucun

Réglages du graphique

Vue: Automatique

Afficher les entités cachées

Propagation du cache aux dimensions inférieures

Afficher les arêtes du jeu de données

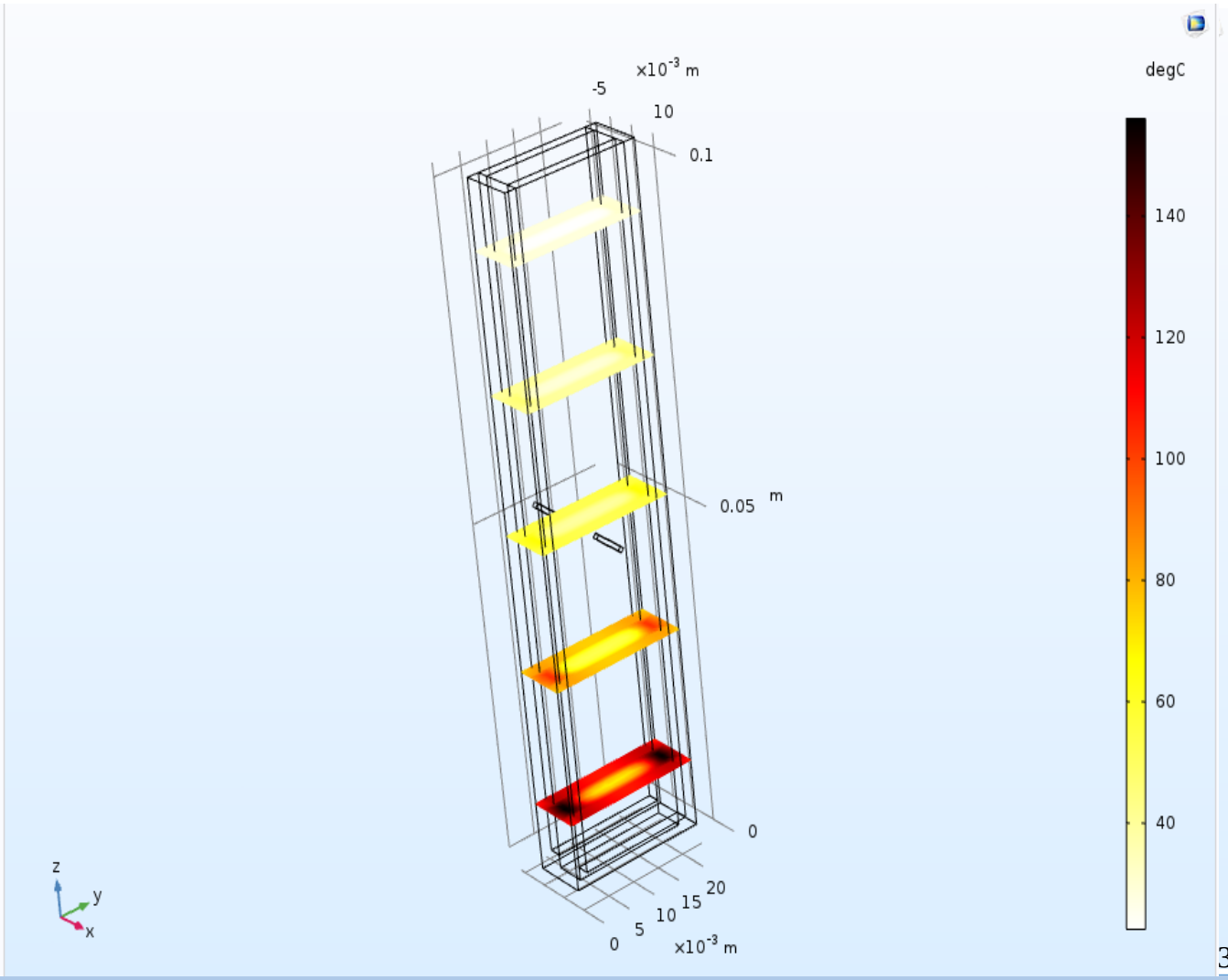
Couleur: Noir

Référentiel: Référentiel matériau (X, Y, Z)

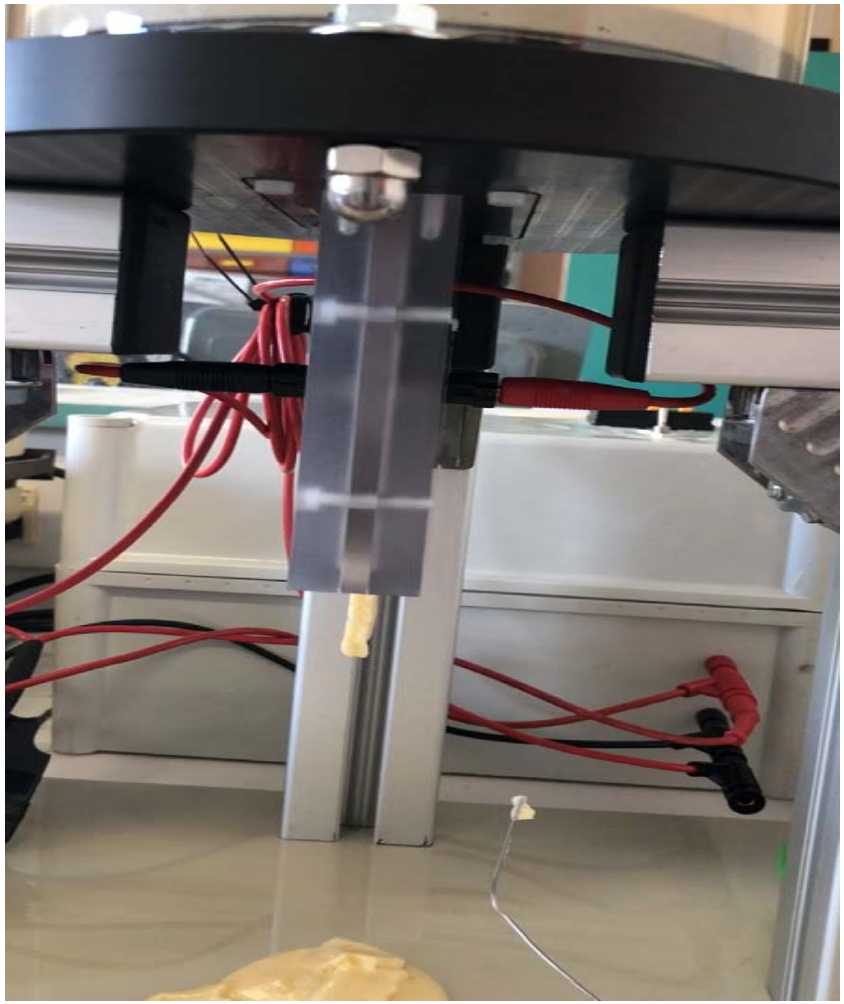
Légende de couleurs

Format de nombre

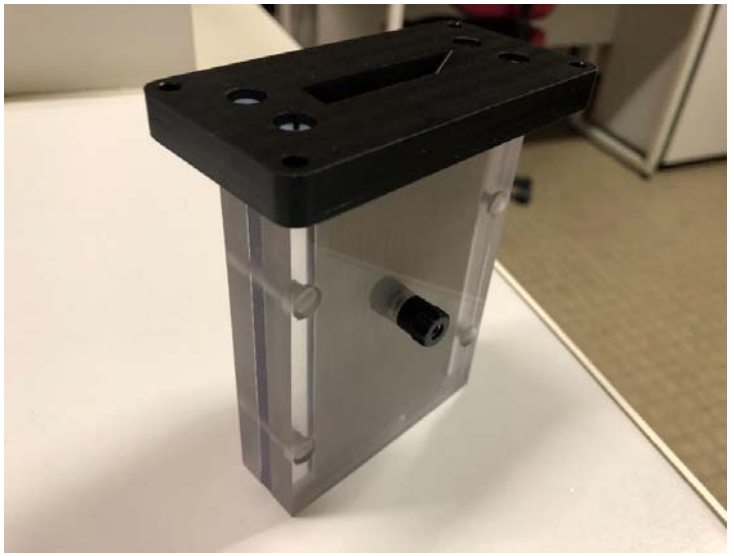
Réglages de la fenêtre graphique

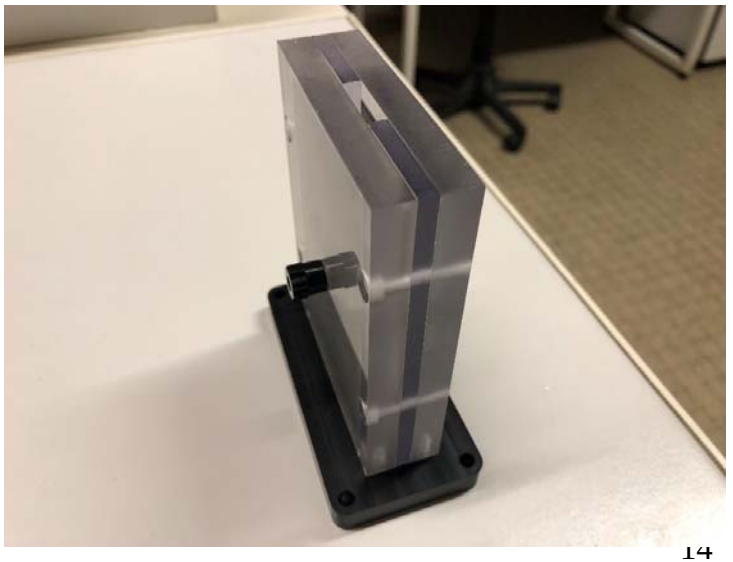


Experimental set-up



3D Printer head
With Ohmic heating





Conclusion

1. Official Validation of the model

2. Modeling of the shear rate variation in our nozzle which is impossible experimentally

3. Optimization of our product by trying to reduce its dimension to fit for 3D printers

THANK YOU FOR YOUR ATTENTION