
Simuler la Fabrication Additive



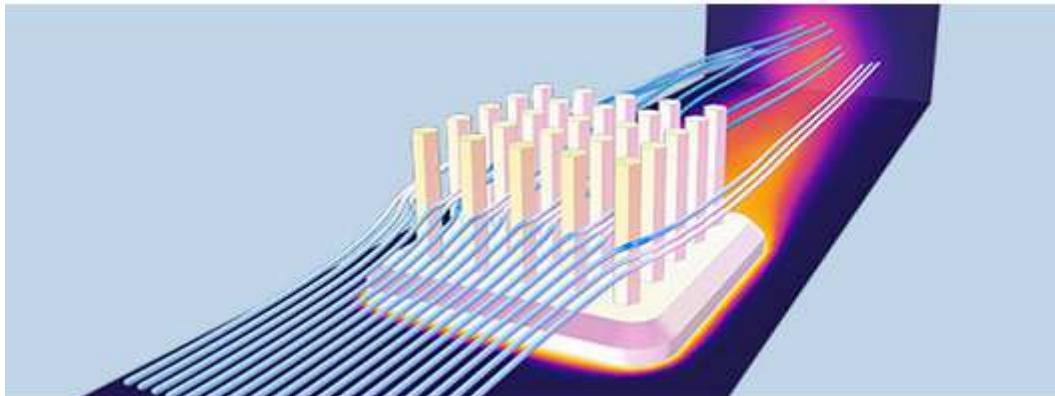
Sébastien Kawka
VP of Applications
COMSOL France



Jean-Marc Petit
VP of Business Development
COMSOL France

Programme

- Un mot sur la fabrication additive & simulation
- Un aperçu de COMSOL Multiphysics®
- Modèles en direct
- Session Q&R



Simuler la Fabrication Additive 2
Frédéric Roger, Ecole des Mines
Juin 2017

Imaginer de nouveaux designs



COMSOL BLOG

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3D Printing: Hottest Topic in Manufacturing

Fanny Littmarck | July 27, 2012

Additive manufacturing, or 3D printing as it is more widely known as, is on everybody's mind right now. Manufacturing folks, engineers, and even the general public have taken an interest in 3D printing. In other words, this is not just a fascinating phenomenon to those in the industry — additive manufacturing has been generally accepted as the next "cool" thing in manufacturing.

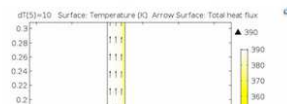
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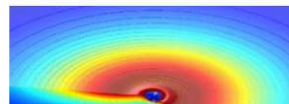
Optimize 3D Printers by Modeling the Glass-Transition Temperature

Caty Fairclough | December 22, 2016



Studying Laser-Material Interaction with Multiphysics Modeling

Aditi Karandikar | May 11, 2016



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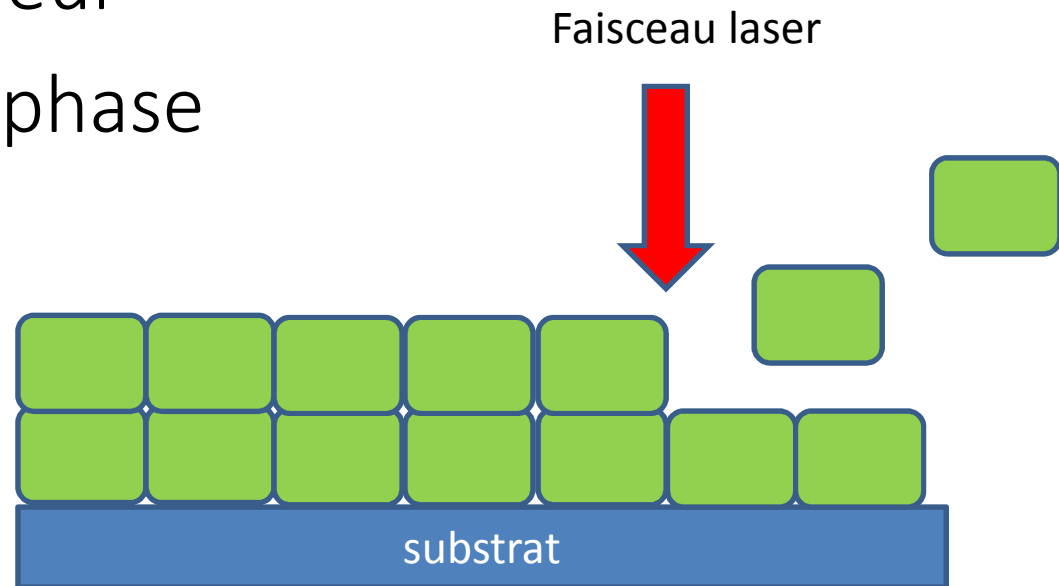
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Couche par couche

- Interaction laser-matière
- Transfert de chaleur
- Changement de phase
- Mécanique
- Topologie
- Forme



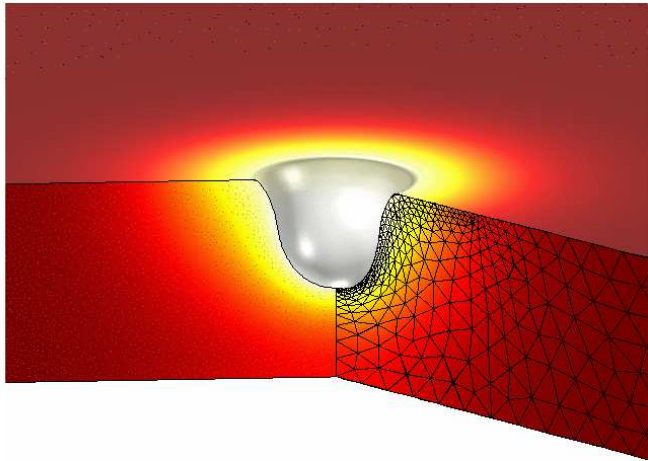
Grain solide ou liquide ?

Simulation en terrain connu : exemple de l'interaction laser-matière

COMSOL BLOG

Modeling Thermal Ablation for Material Removal

Walter Frei | March 30, 2016



Whenever solid materials are heated enough, they will melt and then vaporize to a gas. Certain materials will even go directly from the solid to the gas phase, a process referred to as sublimation or ablation. If the material is heated strongly enough, there will be significant material removal. Today, we will look at how you can model this process in COMSOL Multiphysics.

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COMSOL BLOG

Modeling Laser-Material Interactions in COMSOL Multiphysics

Walter Frei | June 22, 2015



A question that we are asked all of the time is if COMSOL Multiphysics can model laser-material interactions and heating. The answer, of course, depends on exactly what type of problem you want to solve, as different modeling techniques are appropriate for different problems. Today, we will discuss various approaches for simulating the heating of materials illuminated by laser light.

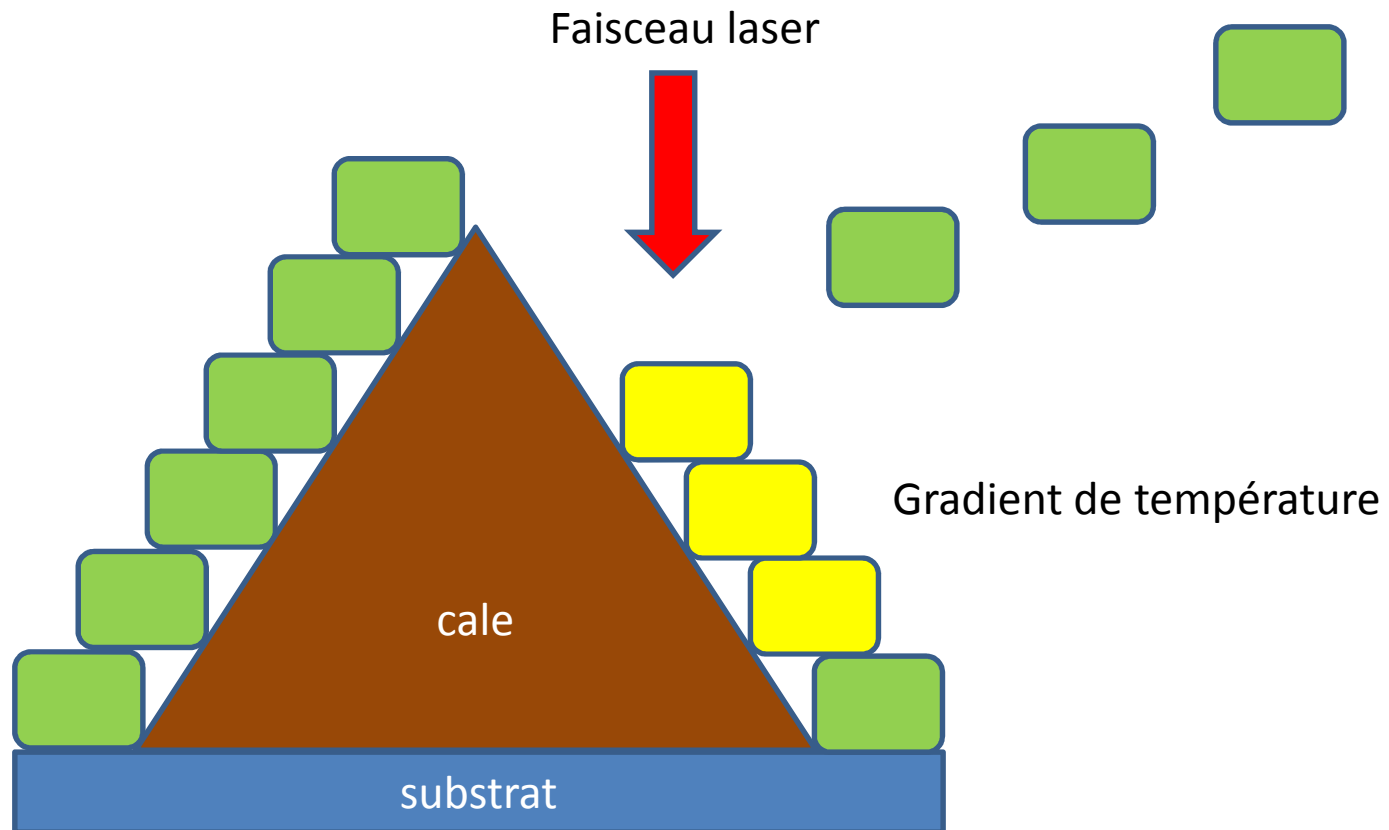
An Introduction to Modeling Laser-Material Interactions

While many different types of laser light sources exist, they are all quite similar in terms of their outputs. Laser light is very nearly single frequency (single wavelength) and coherent. Typically, the output of a laser is also focused into a narrow collimated beam. This collimated, coherent, and single frequency light source can be used as a very precise heat source in a wide range of applications, including [cancer treatment](#), [welding](#), [annealing](#), [material research](#), and [semiconductor processing](#).

When laser light hits a solid material, part of the energy is absorbed, leading to localized heating. Liquids and gases (and plasmas), of course, can also be heated by lasers, but the heating of fluids almost always leads to significant convective effects. Within this blog post, we will neglect convection and concern ourselves only with the heating of solid materials.

 COMSOL

En cours de fabrication



Des questions récurrentes

- Construire une géométrie couche par couche ?
- Prendre en compte en cours de fabrication
 - les contraintes et déformations?
 - le transfert de chaleur ?
- Contraintes résiduelles après fabrication?
 - Matériau final homogène ?
 - Écart avec le design original ?

Multiphysique

Multiphysique

Des questions côté simulation

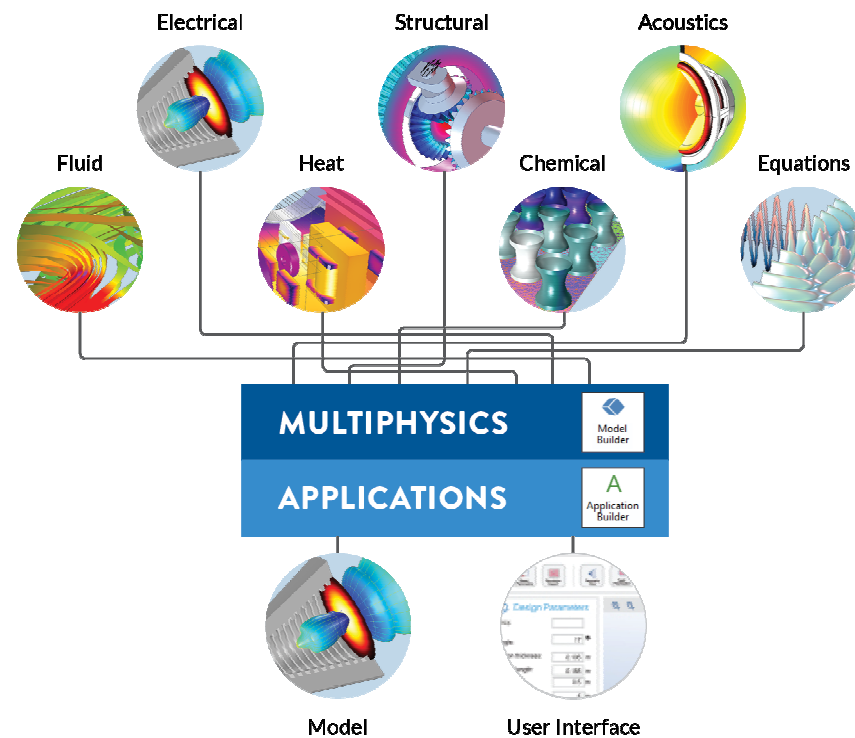
- Prendre en compte le changement de la géométrie (forme & topologie) pour les physiques en jeu ?
 - continuité de la solution
- Savoir quand on passe de couche en couche ?
 - Difficile à connaître a priori

Assemblage

Maillage mobile

Evènement

COMSOL Multiphysics®

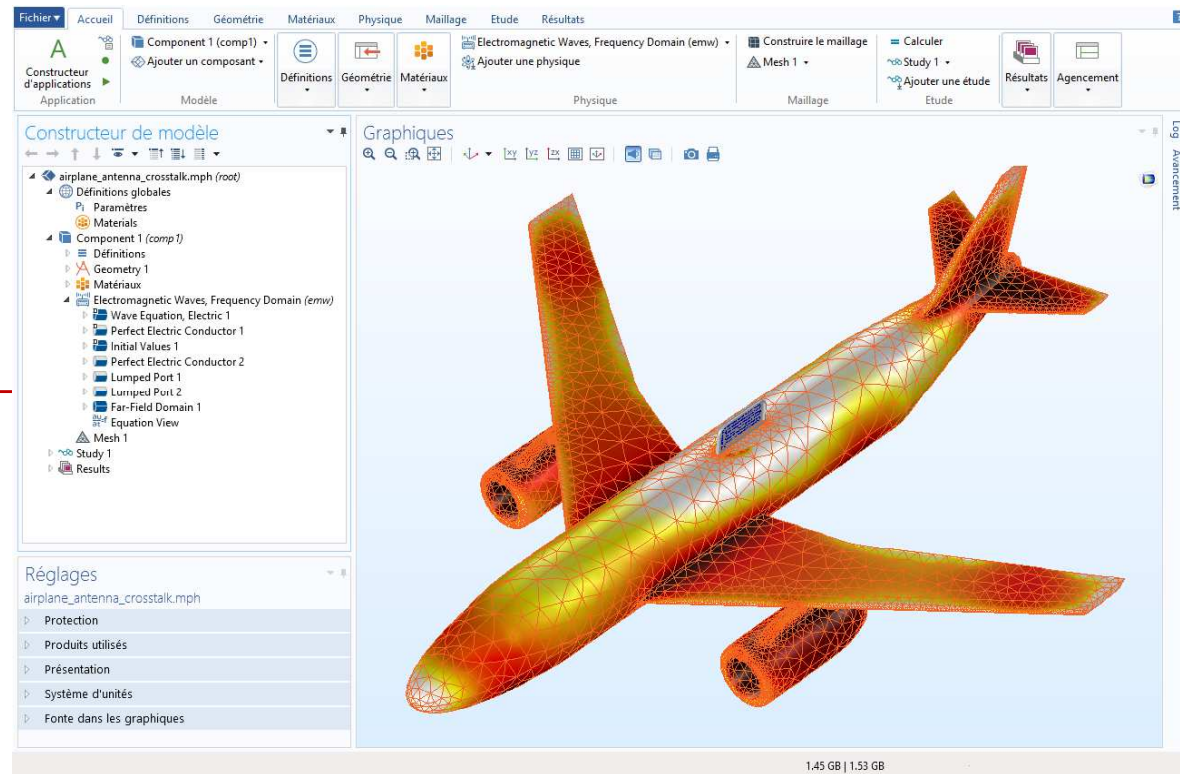


Un environnement de Simulation

Constructeur de Modèle

Fournit un accès instantané aux réglages du modèle

- CAD/Géométrie
- Matériaux
- Physiques
- Maillage
- Solveurs
- Résultats



Création d'Applications spécifiques

Une application
N'importe quel modèle
peut être converti en
une application simple

Application Builder
Construction et test
des applications

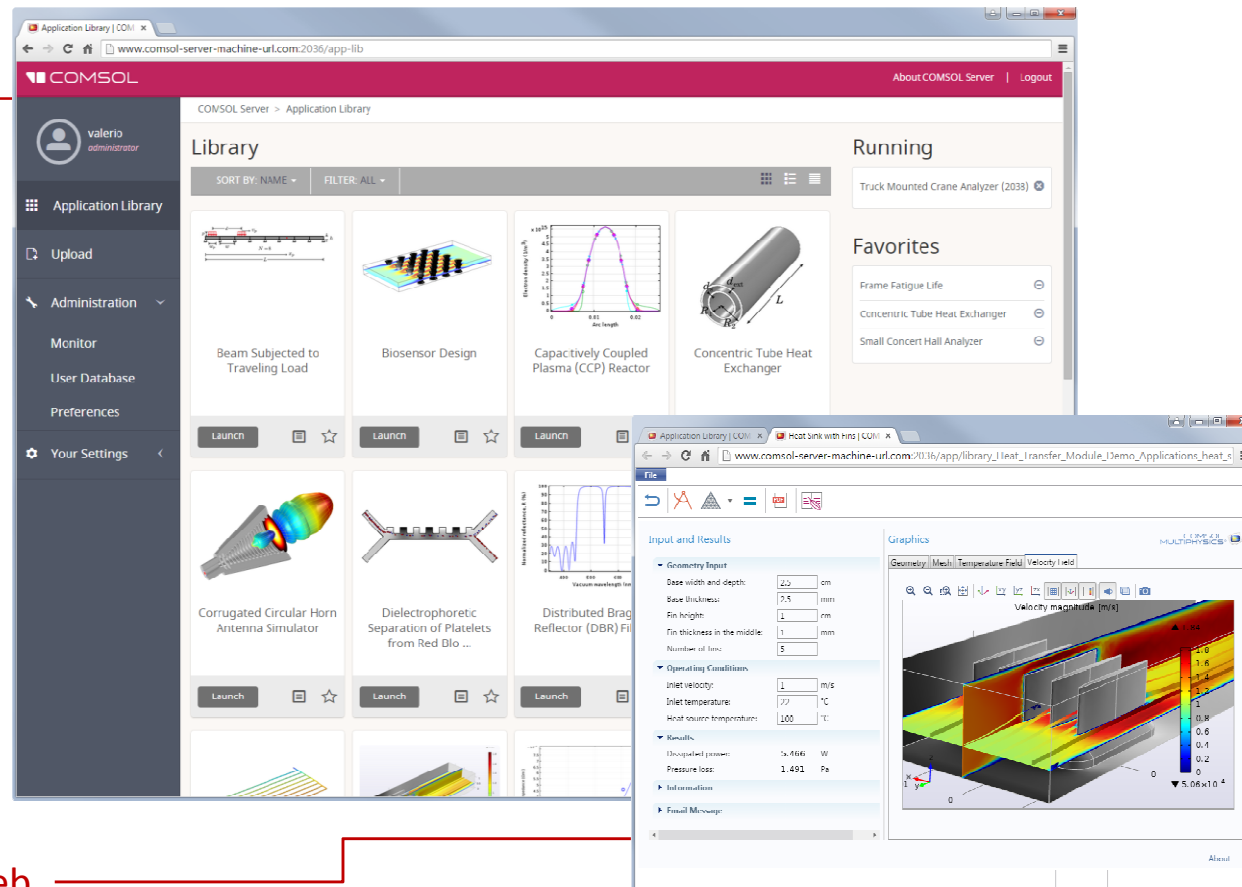
The screenshot displays the COMSOL Touchscreen Simulator interface. The top menu bar includes 'File' and the COMSOL logo. The main window is titled 'Touchscreen Simulator' and is divided into several sections:

- Geometry Parameters:** Includes fields for Finger location (x: 0 mm, y: 0 mm), Angle (20°), Touch level (Soft), PET Thickness (250 um), Electrodes Array size (x: 10, y: 10), Unit cell size (2 mm), Glass Thickness (top: 0.4 mm, bottom: 0.2 mm).
- Material Properties:** Lists Permittivity values for Glass (top: 2.09, bottom: 2.09), PET (4), ABS case (2.1), and Finger (80).
- Command Console:** Contains buttons for Compute, Reset, Geometry, About, and Report.
- Information:** States 'The computation time is expected to be around several minutes with the default parameters. It varies based on the size of the geometry.' and shows 'Last computation time: 5 min 14 s'.
- Geometry Preview:** A 3D visualization of a finger touching a grid of electrodes on a substrate.
- Result Plot:** A 3D surface plot titled 'Electric Field Norm (dB)' showing the distribution of the electric field across the electrode array. A color scale on the right ranges from -40 to 60 dB.

At the bottom of the interface, there are controls for 'Electrode group number' (set to 1) and checkboxes for 'Deformation' and 'Case'. The COMSOL logo is visible in the bottom right corner of the interface.

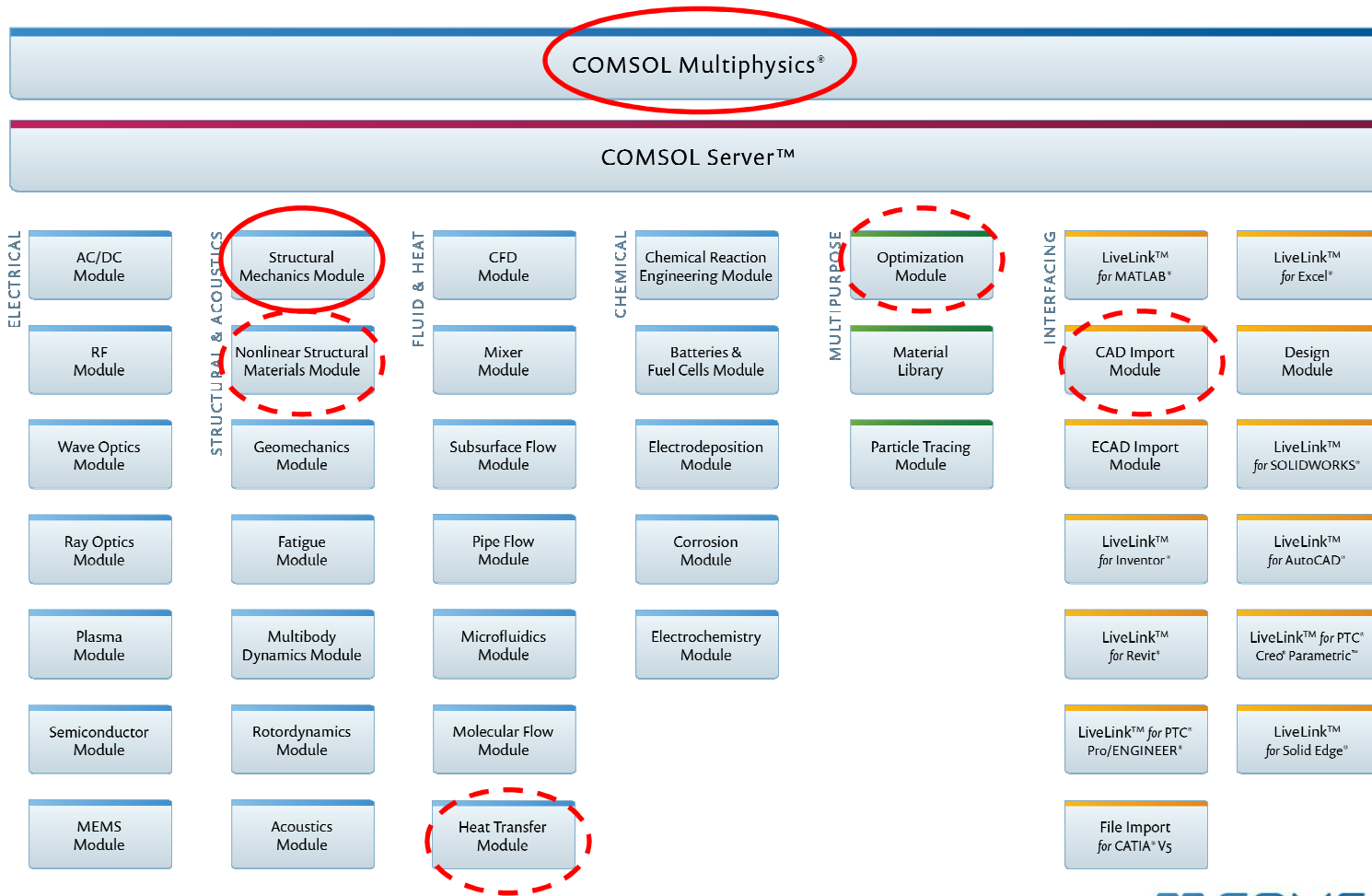
Déployer avec COMSOL Server

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Déploiement
Accès à distance
Contrôle de l'utilisation



Accès via le web

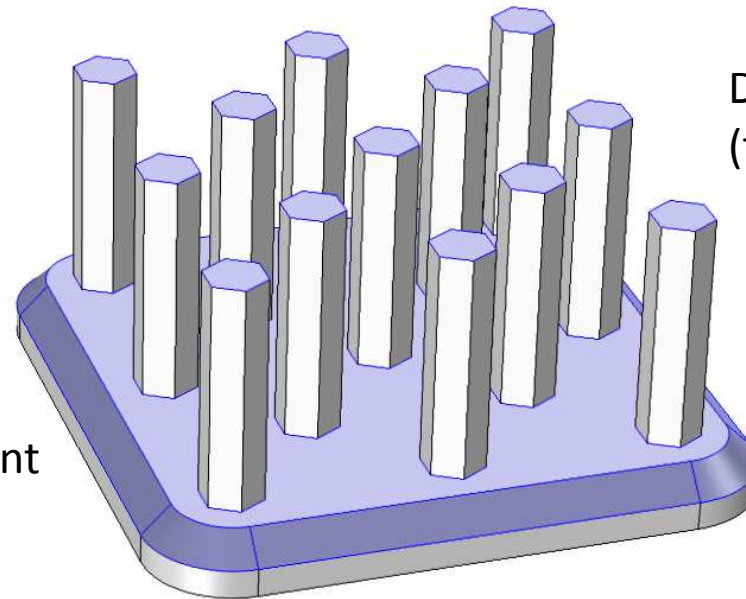
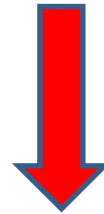
Produits – COMSOL® 5.2a



Thermo-dilatation

Matériau : acier

Flux de chaleur – Puissance = 500W

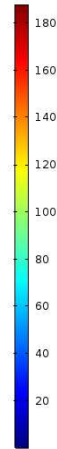
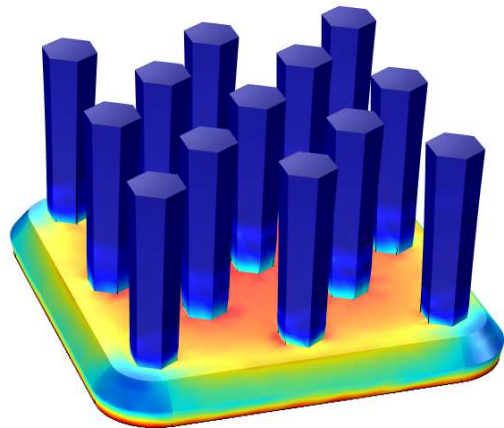


Dissipation thermique par l'air
(flux de chaleur convectif)

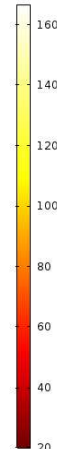
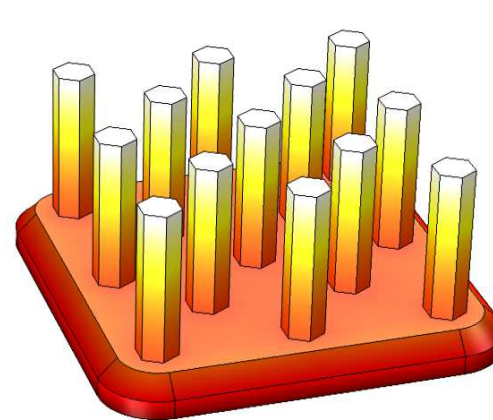
Encastrement
De la base

Résolution temporelle de 0 à 2s

Résultats à $t=2s$



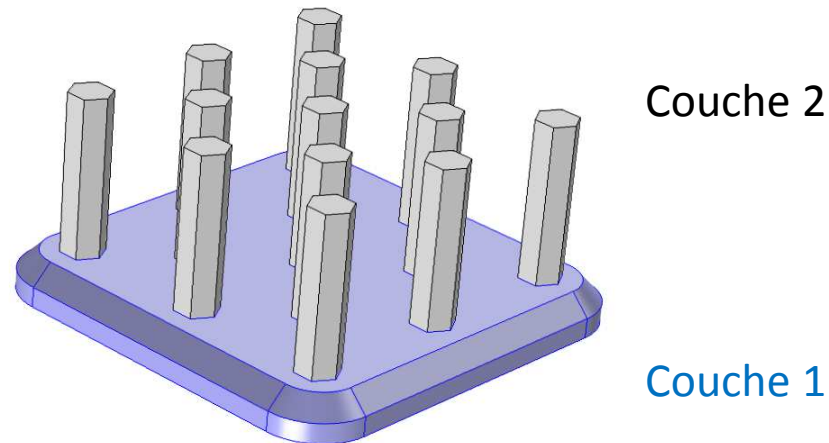
Contraintes de von mises (MPa)



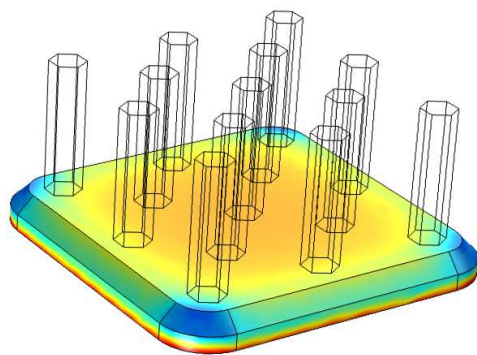
Température (°C)

Construire une géométrie couche par couche

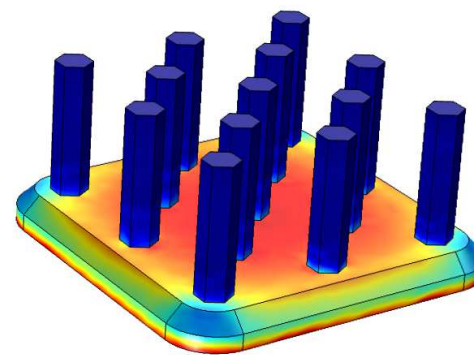
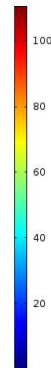
- Découper en couche la géométrie initiale et activer successivement les domaines
 - Activation d'un bloc de la couche ? A quelle étape ?



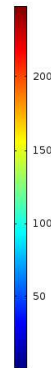
Contraintes de von mises (MPa)



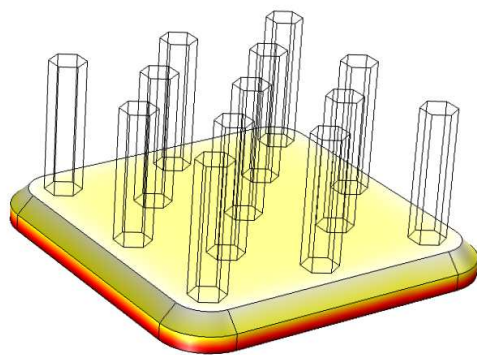
À 1s



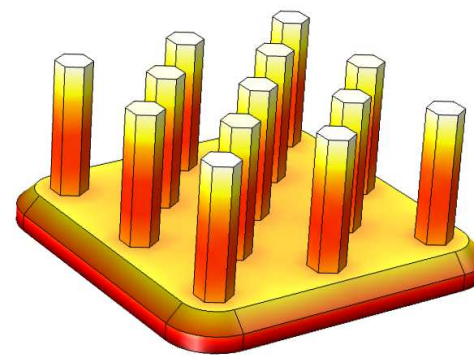
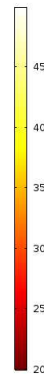
À 2s



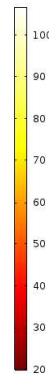
Température (°C)



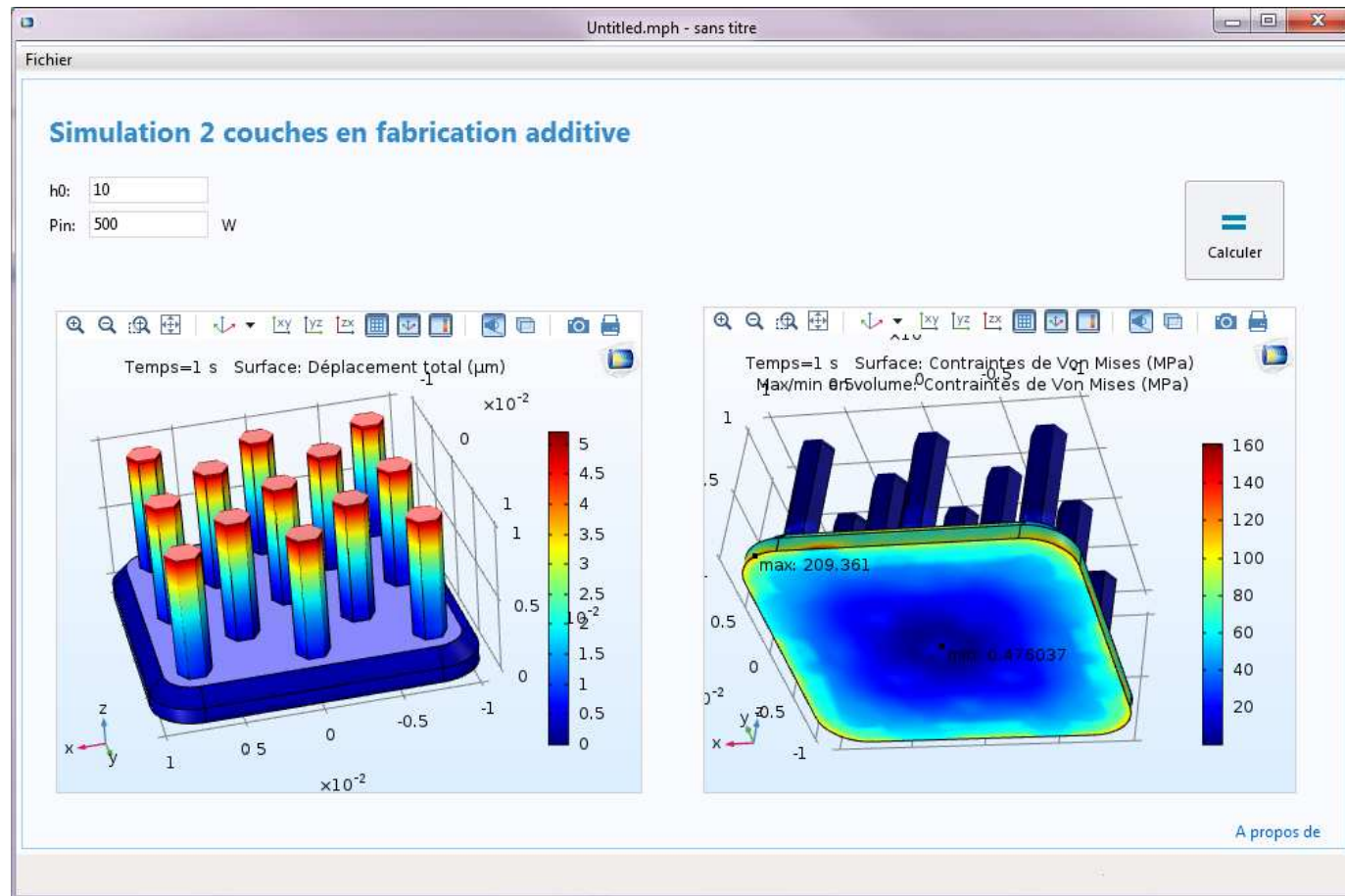
À 1s



À 2s

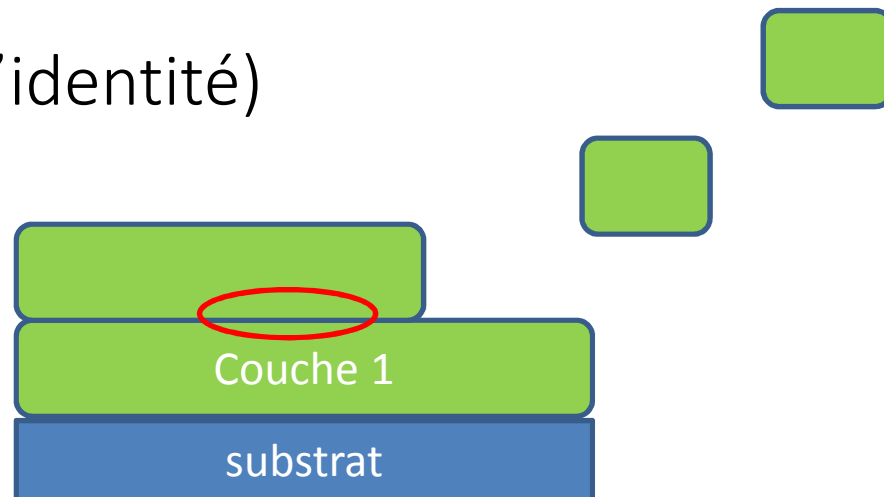
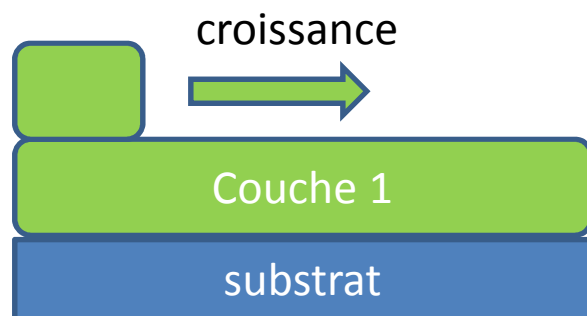


Automatisation : créer une application



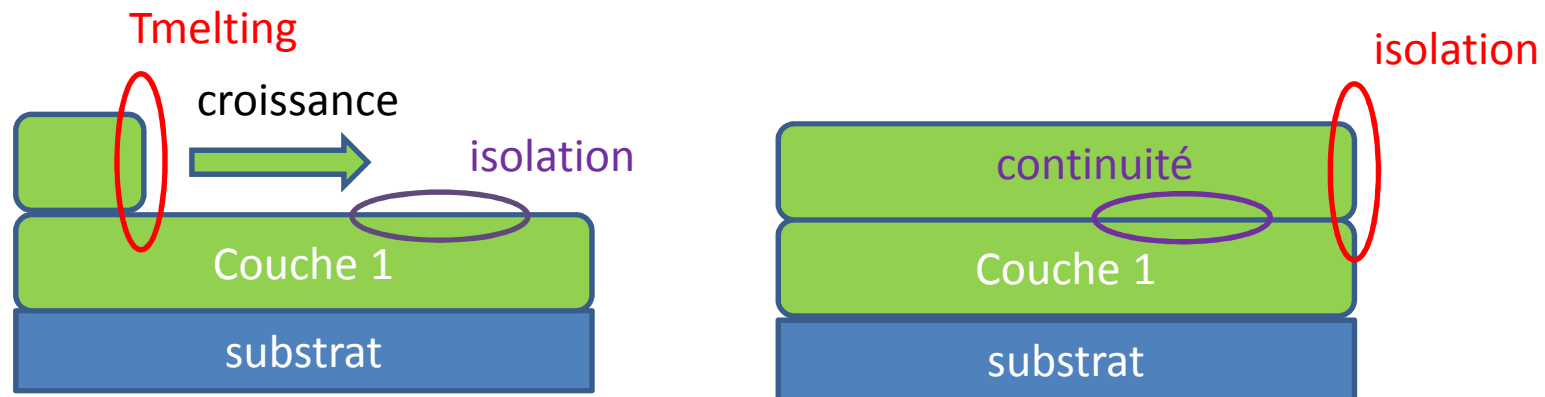
Construire une couche 1/3

- Croissance d'une couche ?
 - Maillage mobile (géométrie paramétrée)
- Continuité entre couches ?
 - Assemblage (paire d'identité)



Construire une couche 2/3

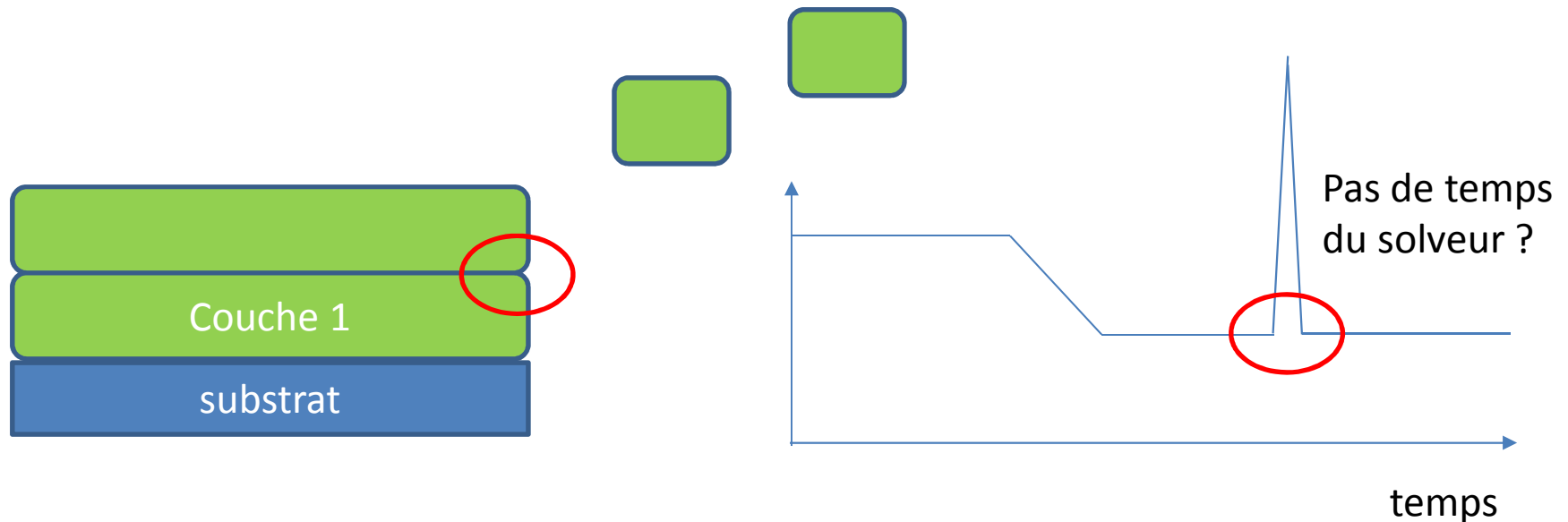
- Variation de la condition limite dans le temps ?
 - Condition limite conditionnelle



+ Opérateur d'intégration
+ Lissage (fonction step)

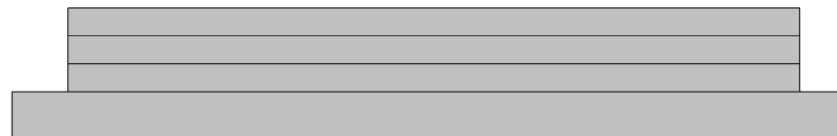
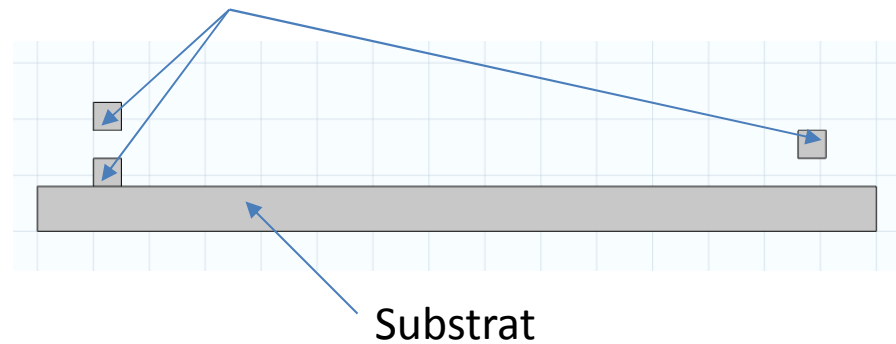
Construire une couche 3/3

- Quand arrive t on au bout d'une couche ?
 - Évènement



Géométrie initiale et finale

Géométrie initiale pour l'ajout de 3 couches



Géométrie finale

3 Paires d'identité

- Les paires d'identité permettent de connecter le substrat avec la première couche, et les différentes couches entre elles



Paire entre le substrat et la première couche



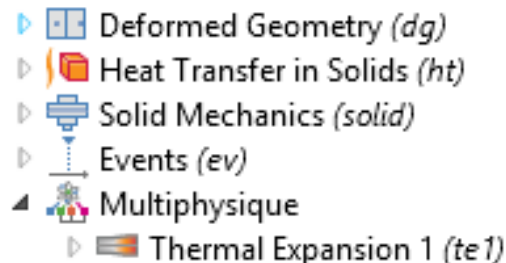
Paire entre la seconde
et la troisième couche



Paire entre la première et la seconde couche

Interfaces physiques

- Une interface de géométrie déformée est utilisée pour étirer les couches à partir de leur forme initiale. Le but est d'ajouter le matériau, couche par couche, à une vitesse définie
- La température de dépôt du matériau est fixée au niveau du front de croissance avec l'interface de transfert de chaleur
- La thermo-dilatation est calculée avec une interface de mécanique
- Une interface Evènement aide le solveur à sélectionner les pas de temps appropriés



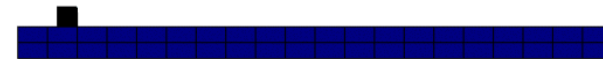
Résultats - Animation

Résistance thermique de contact
entre les couches

Continuité entre les couches



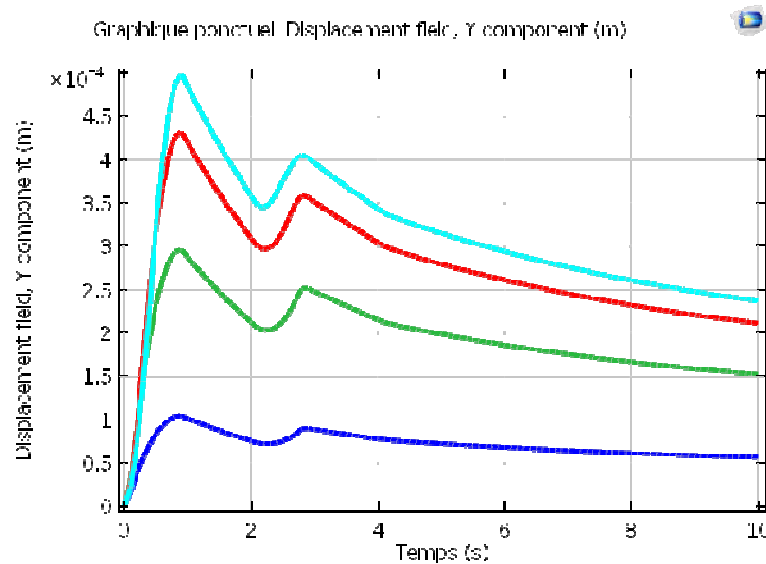
Température



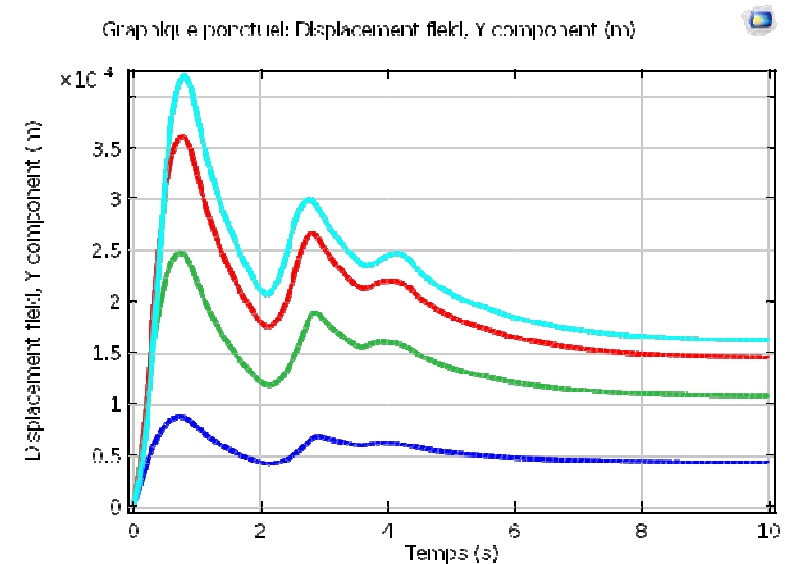
Contraintes de von Mises

Déplacement vertical (m)

- aux points suivants

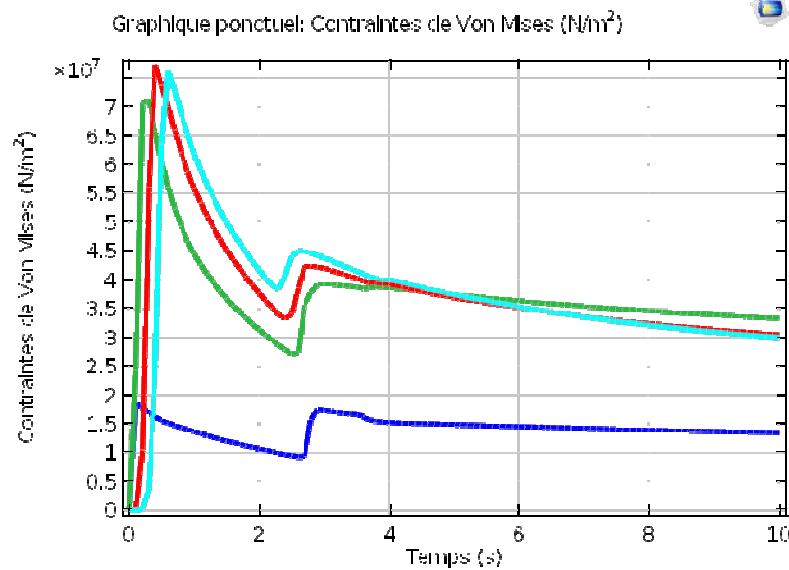


En condition de couche mince isolante

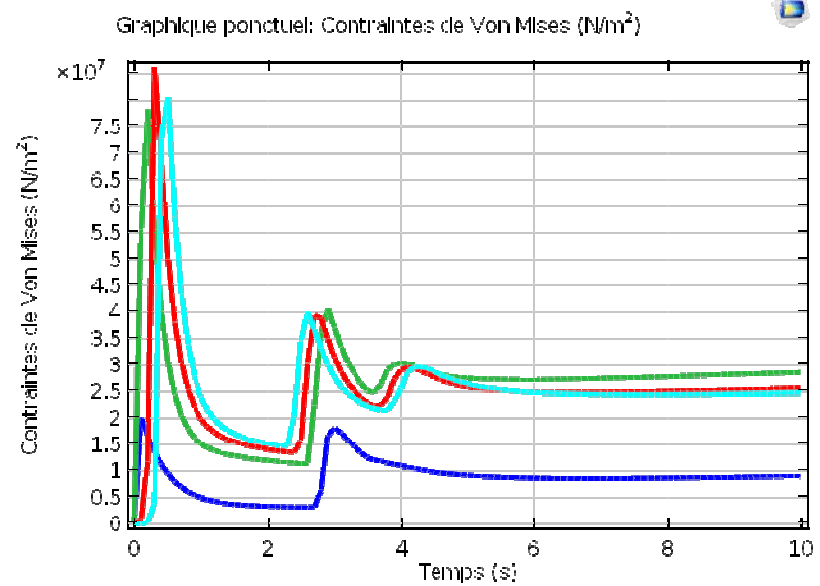


En condition de continuité

Contraintes de von Mises (Pa)



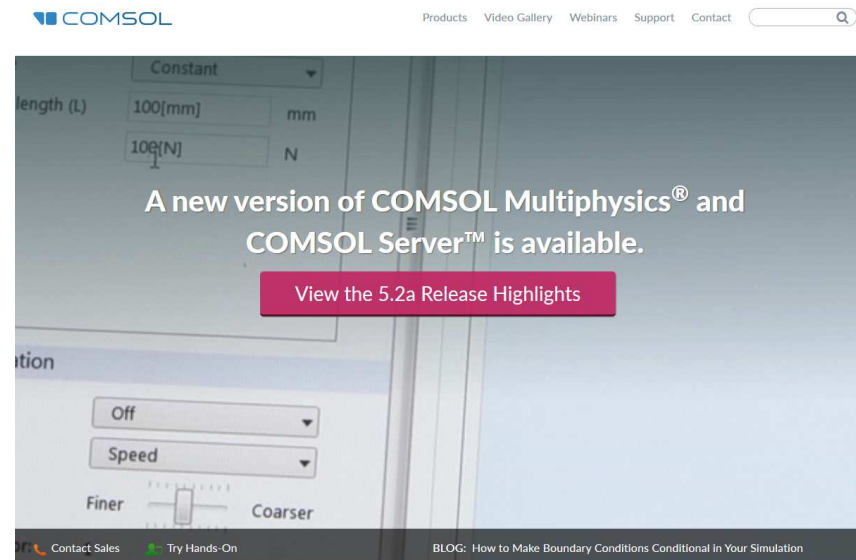
En condition de couche mince isolante



En condition de continuité

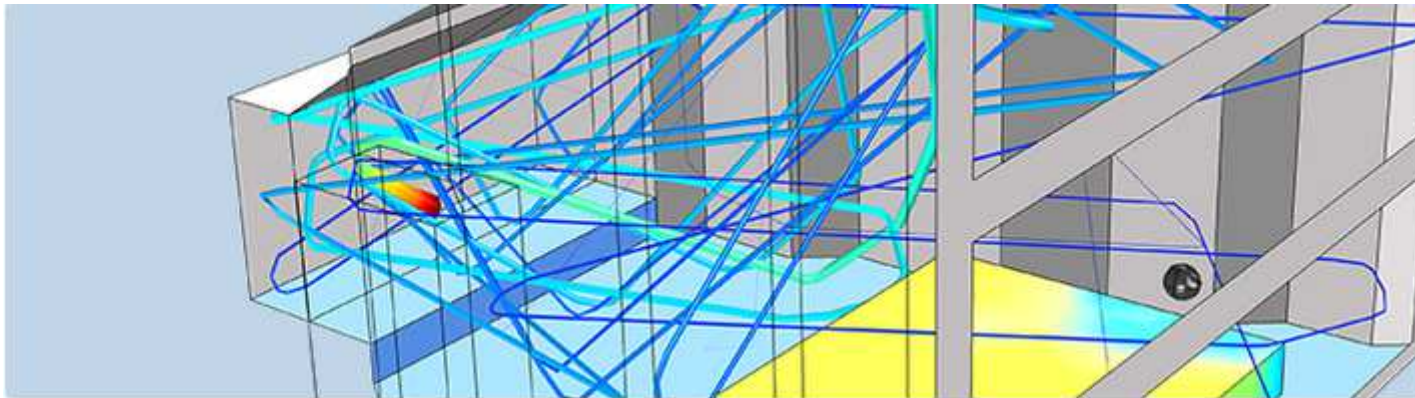
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