A DISCUSSION TO MODEL EXOTHERMIC REACTIONS AND IRREVERSIBLE VARIATIONS OF ELECTRICAL CONDUCTIVITY

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OUTLINE

- CONTEXT AND OBJECTIVES
- SIMULATION OF EXOTHERMIC REACTION WITH COMSOL
- SIMULATION OF IRREVERSIBLE VARIATION OF CONDUCTIVITY
- RESULTS
- FEEDBACK

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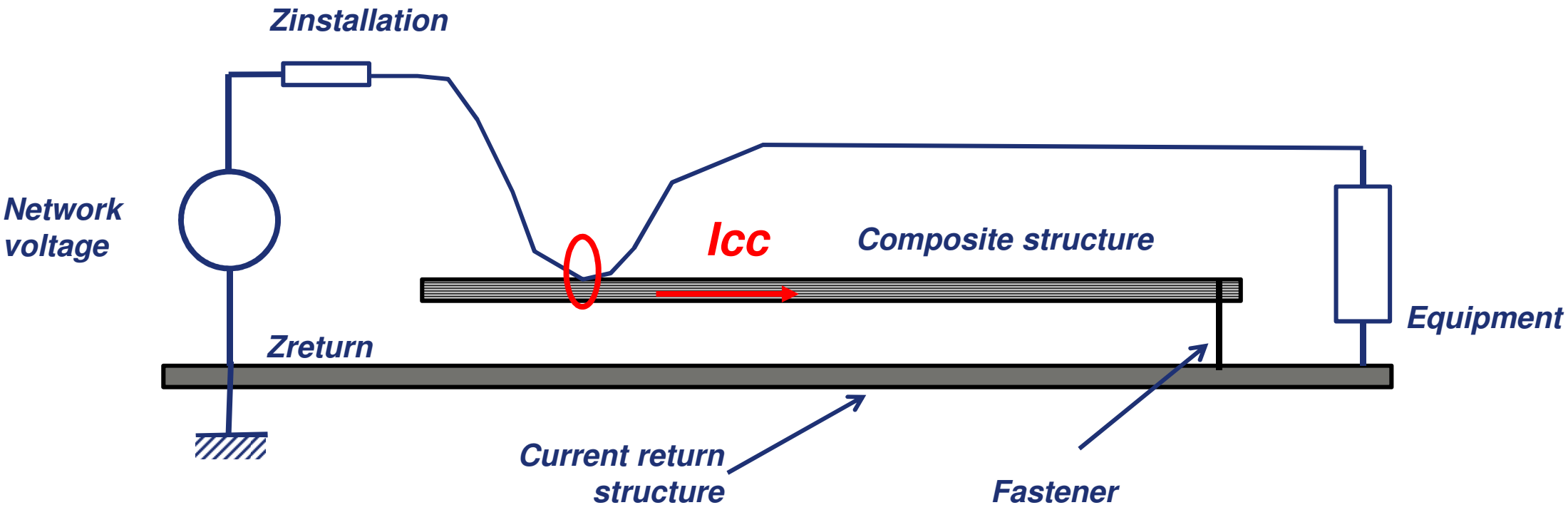
STUDY CONTEXT

- A350: first aircraft in Airbus with composite fuselage.
- Incidental contact between cable and composite structure (e.g. chaffing);
- Current *Icc* into composite.



Design of a safe aircraft installation + protection devices => short-circuit has **no consequence**.

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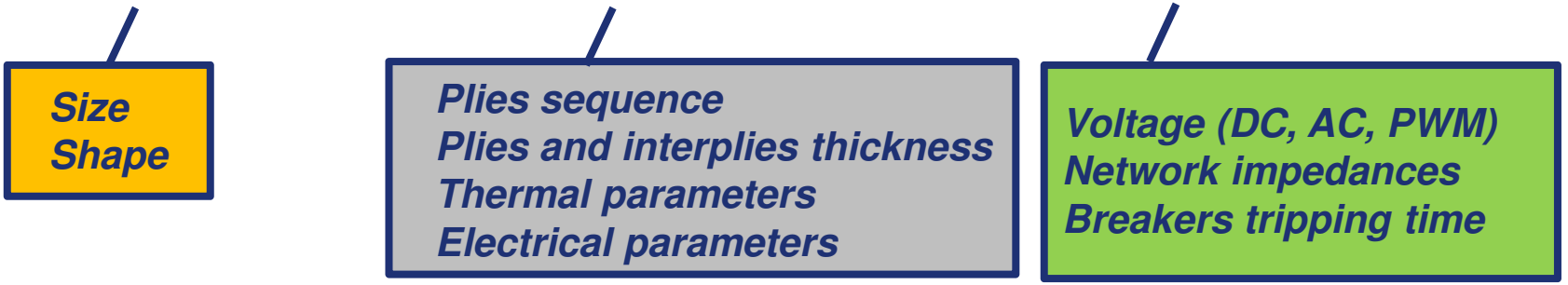
OBJECTIVES

Tomorrow:
- New composite materials;
- Different installations;
- Different protection devices (circuit breakers, solid-state…)
- Different voltages (e.g. 540VDC);

Limitation of physical tests (repeatability, cost, duration)

⇒ Numerical tool for predicting the damage;

Damage = f (composite, aircraft installation)



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PHENOMENA TO SIMULATE

- Strong coupling between Electric and Thermal;
- Carbon fibers anisotropy;
- Exothermic thermo-oxidation of resin;
- Irreversible variation of electrical conductivity;
- Influence of circuit impedance and generator regulation.

=> Comsol Multiphysics

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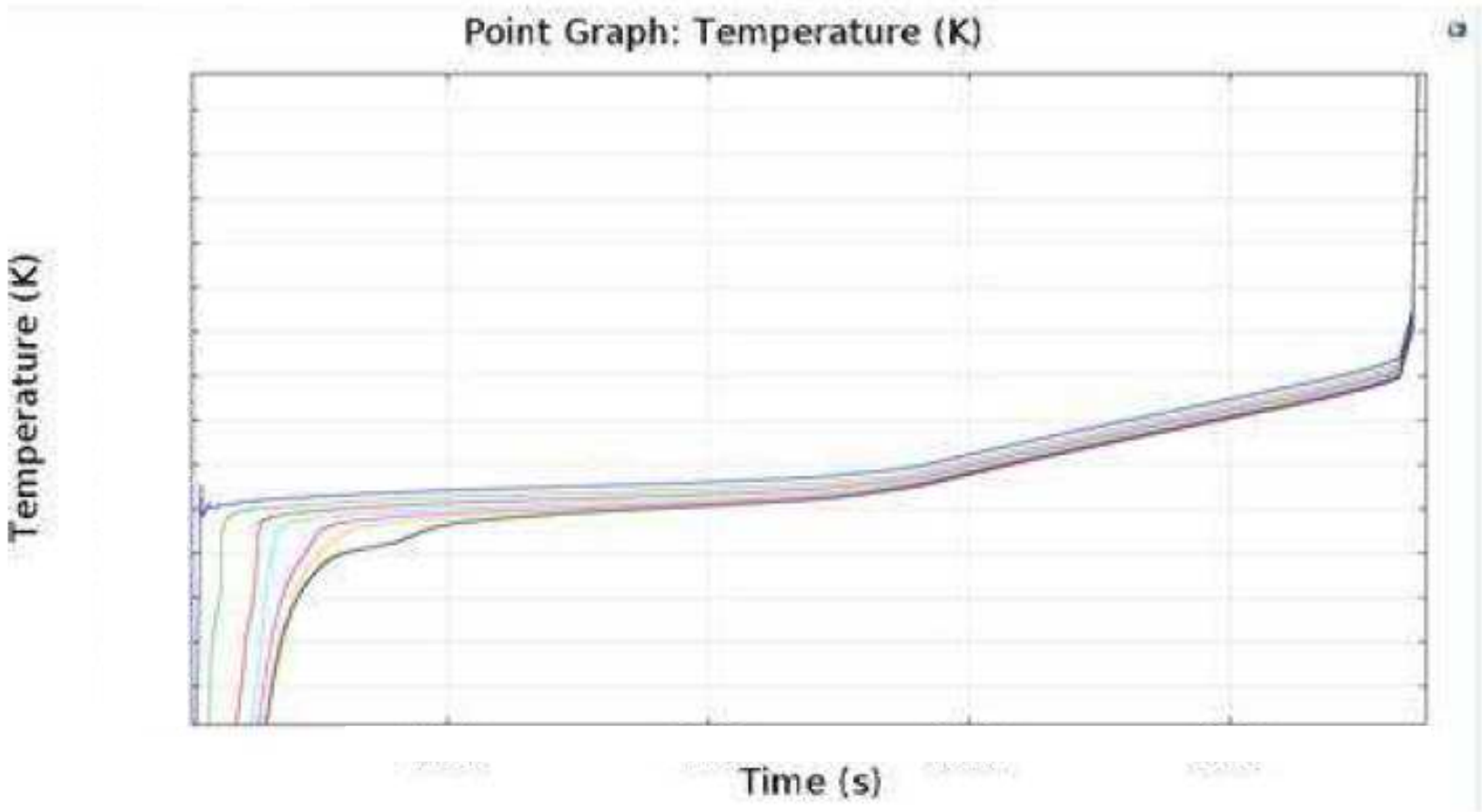
SIMULATION OF EXOTHERMIC REACTION

Simulation with Comsol



- Resin thermo-oxidation is exothermic (DSC / TGA measurements);
- Heat transfer in solid / Phase change = problem: temperature rise decreases !!! => simulated phenomenon is endothermic.

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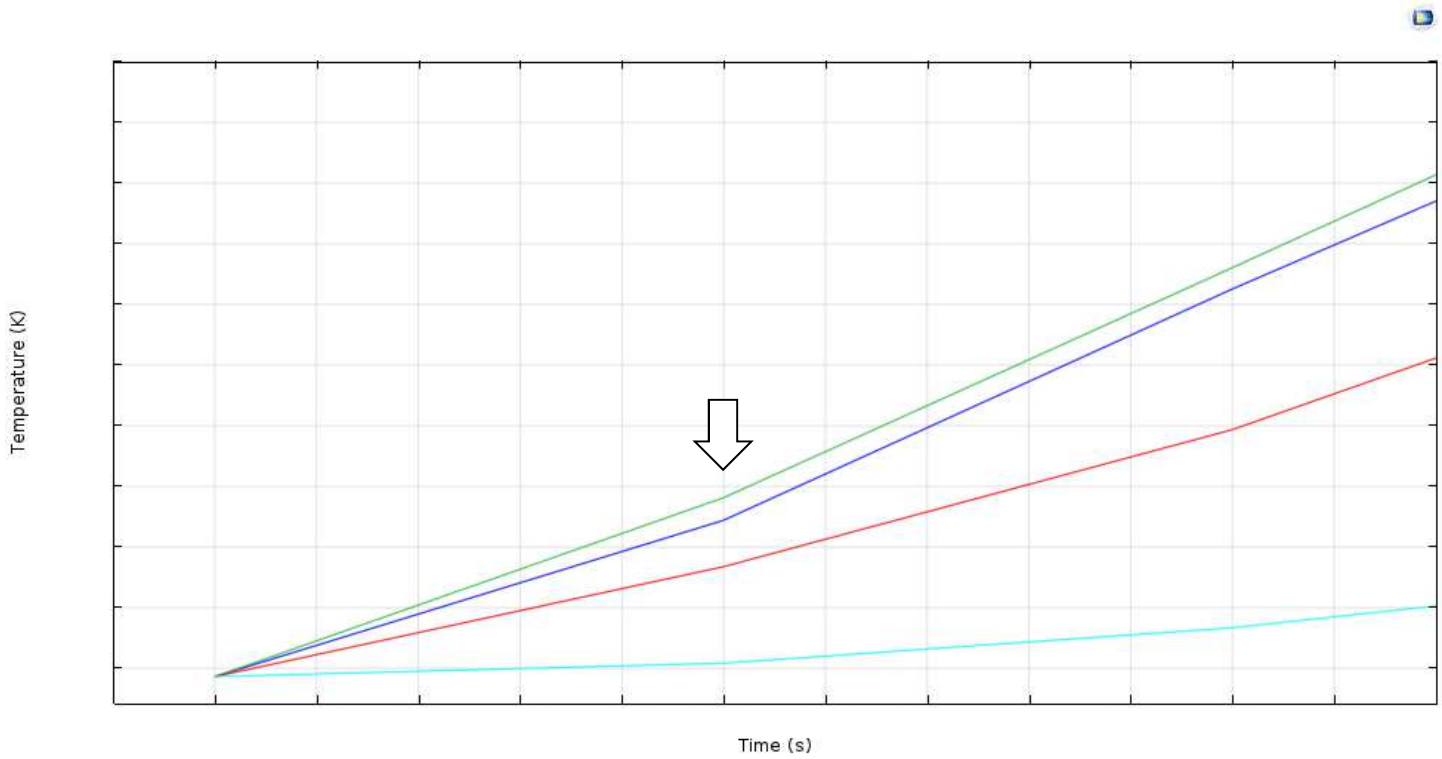
SIMULATION OF EXOTHERMIC REACTION

Solution

- Reaction progress: $\frac{dm}{dt} = -k \times m(t)$
- Local heat power density: $Q(t) = k \times m(t) \times d \times \Delta H$

with m: mass, k: kinetics, d: density, ΔH: enthalpy.



Temperature rise increases !!! => Exothermic reaction => OK.

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SIMULATION OF IRREVERSIBLE VARIATION OF ELECTRICAL CONDUCTIVITY

- Physical phenomenon:
  - Local conductivity is: $\sigma = \sigma_1$ (undamaged) => σ_2 (damaged).
  - Shifting is triggered by critical temperature T_0.
  - Phenomenon is irreversible.

- 1st attempt:

$\sigma = \sigma_1 \times (1-E) + \sigma_2 \times E$, with E=nojac(if(T> T_0),1,0)

$\Rightarrow$ Works but very non-linear behavior.

- 2nd attempt:

$$\sigma = \boldsymbol{f(m)} \times \boldsymbol{b}$$

$$\frac{\boldsymbol{dm}}{\boldsymbol{dt}} = -\boldsymbol{k} \times \boldsymbol{m(t)} \times \boldsymbol{b}$$

With b: boolean=1 if T> T_0 => latching of last computed values.

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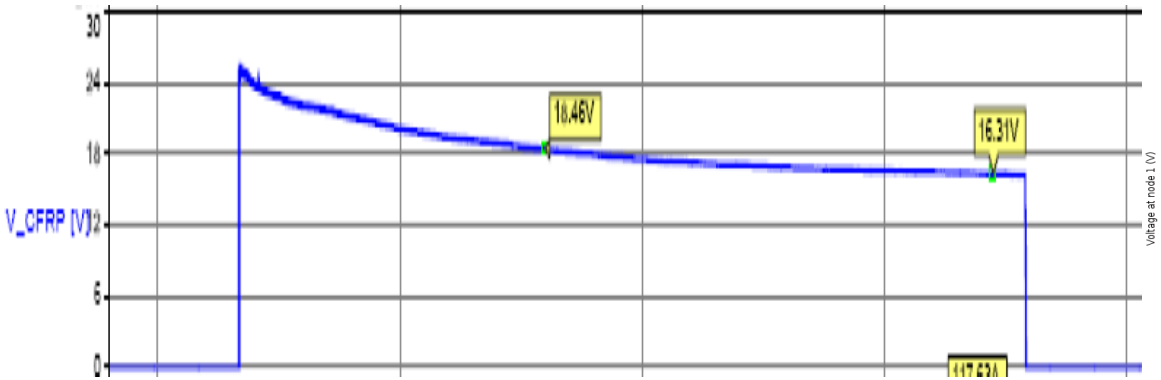
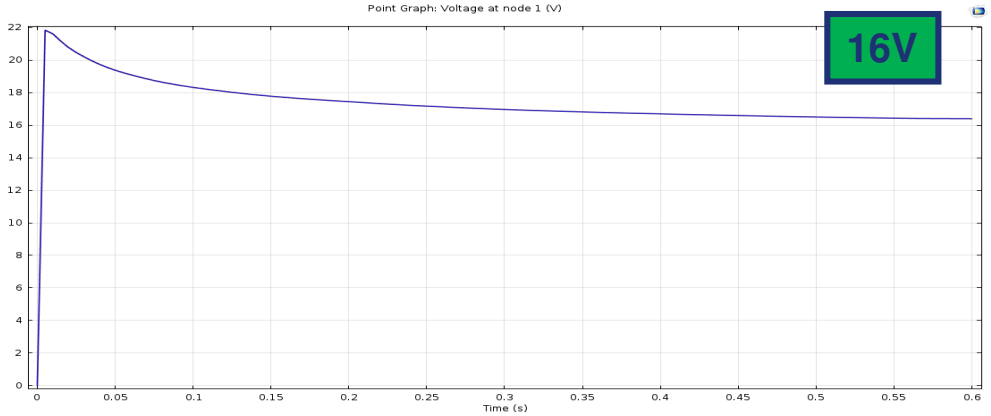
RESULTS

Correlation between tests and simulation

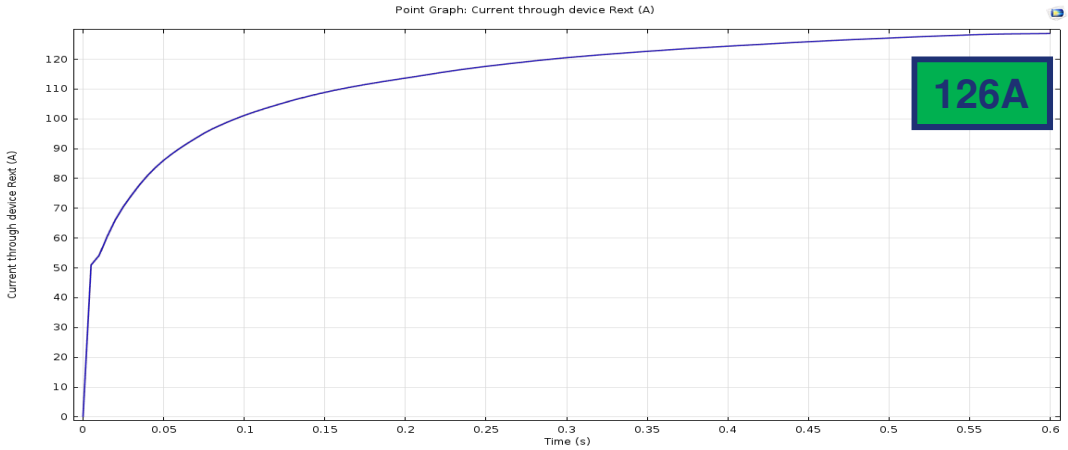
EXPERIMENT



MODELLING



t=600 ms



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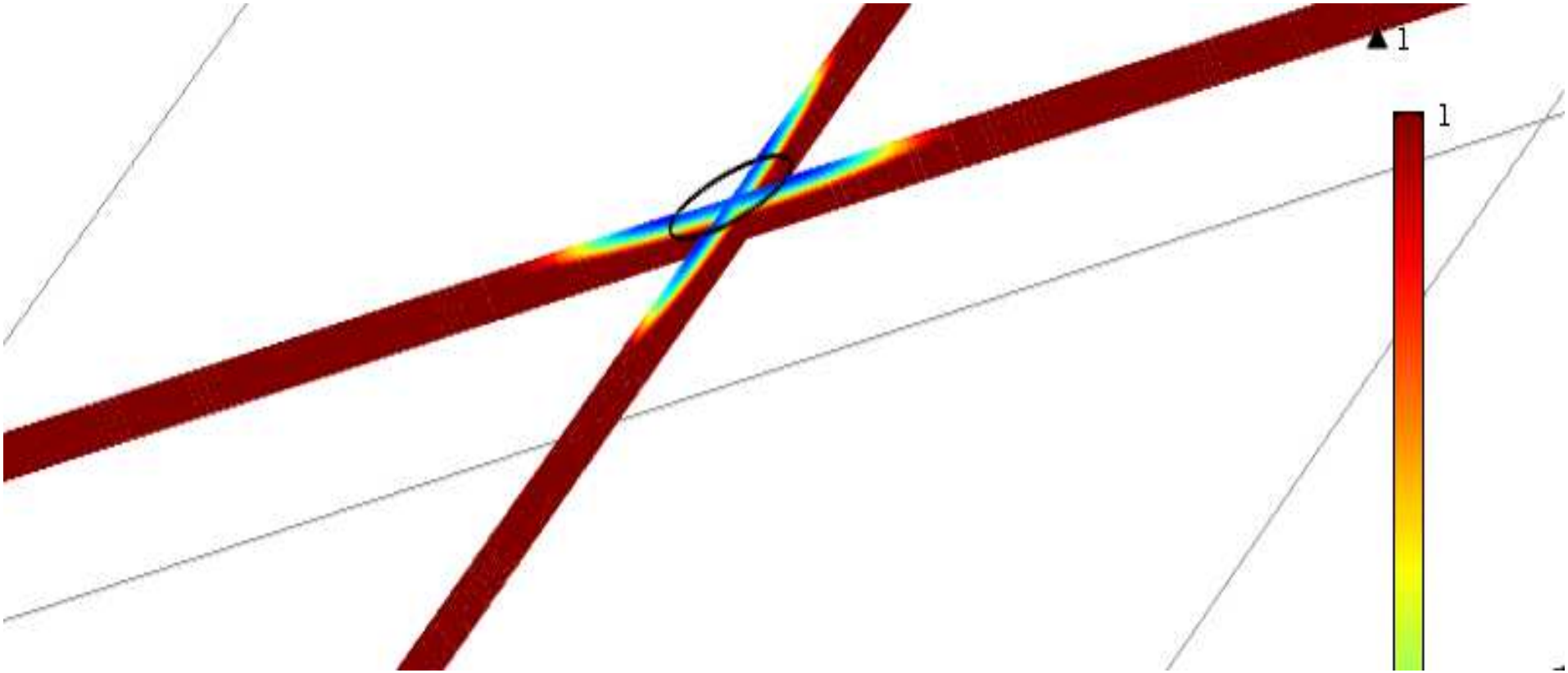
RESULTS

Example of mass loss mapping



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FEEDBACK

- Computation of the damage, with the various multiphysics phenomena with Comsol Multiphysics => Target achieved !

- No possibility to simulate exothermic phenomena with « Heat transfer with phase change » => need to « create » a local power density function;

- Long computing times: 24 to 48h for a problem with xxxx numbers of freedom (workstation: multicores processor Intel ® Xeon ® CPU E5-1650 v3@3.5 GHz, 128 GB RAM , OS Windows 7, 64 bits)

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Merci !

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