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Thermo Mechanical Behavior of Heat Exchangers

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Thermo Mechanical Behavior of Heat Exchangers

- Aim of the study
- Thermal loading
- Mechanical behavior law
- ThM modeling of inlet critical zone
- Conclusion

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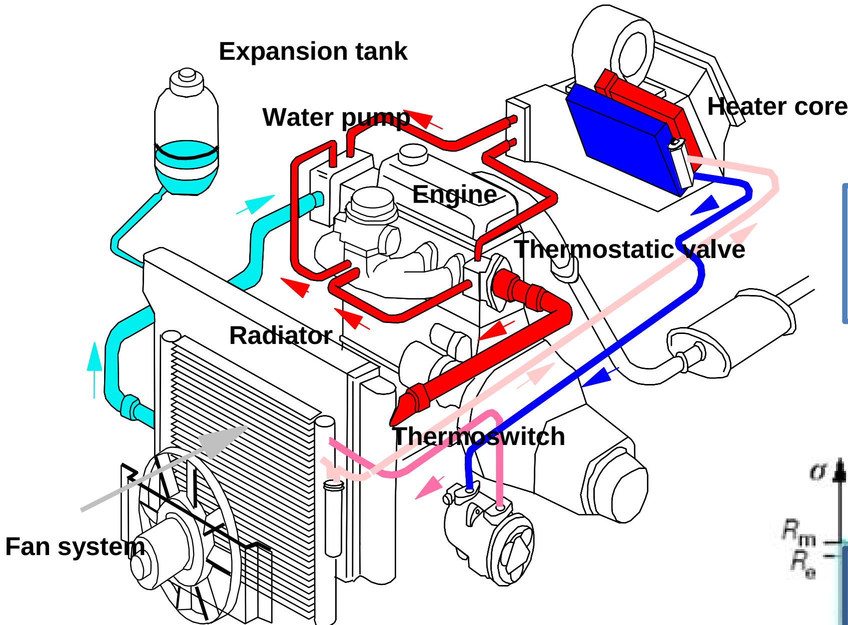
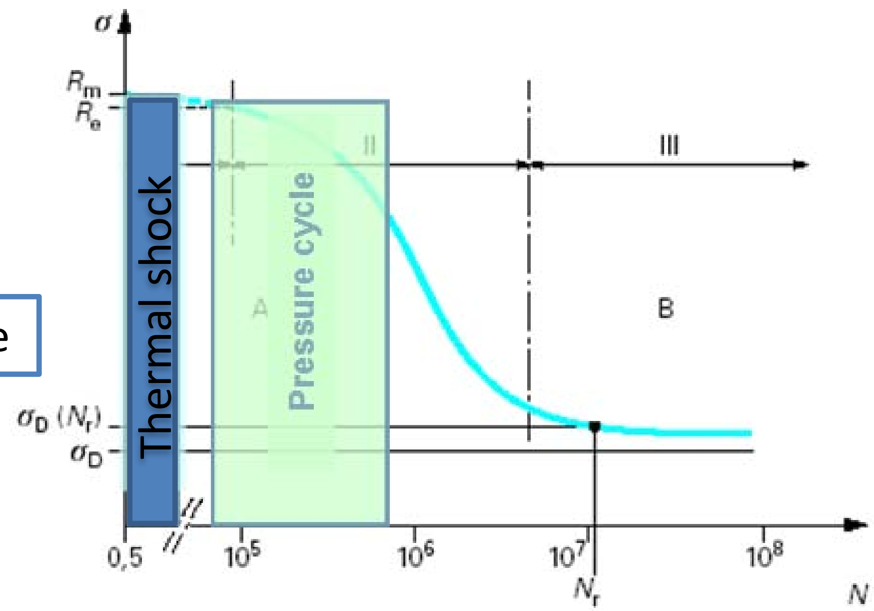
Introduction



Sketch of an automotive cooling system



Stress/Nb cycles curve

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Introduction

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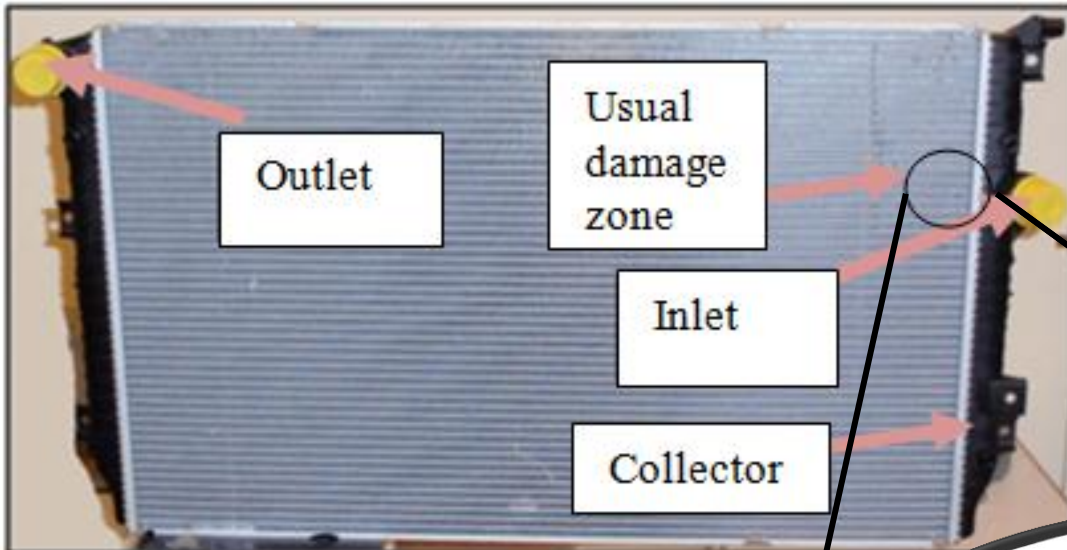
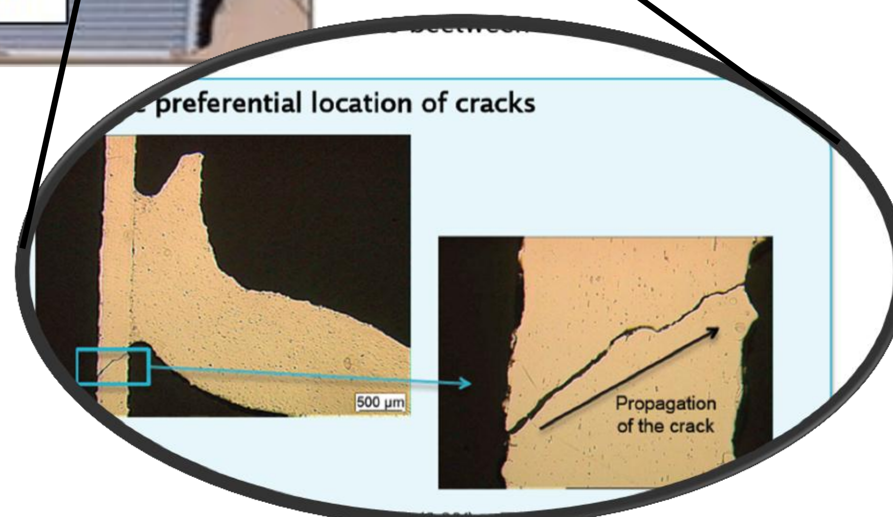


Usual automotive heat exchanger



Study a tube with a periodic thermal shock loading

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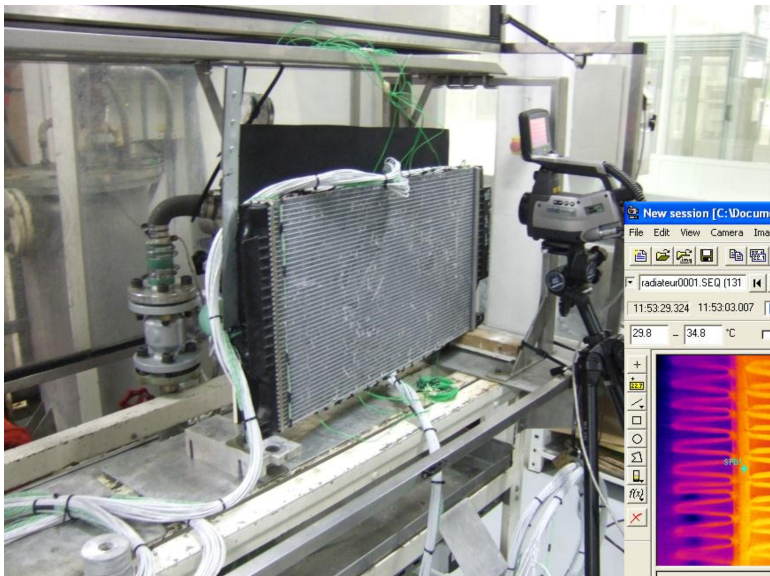
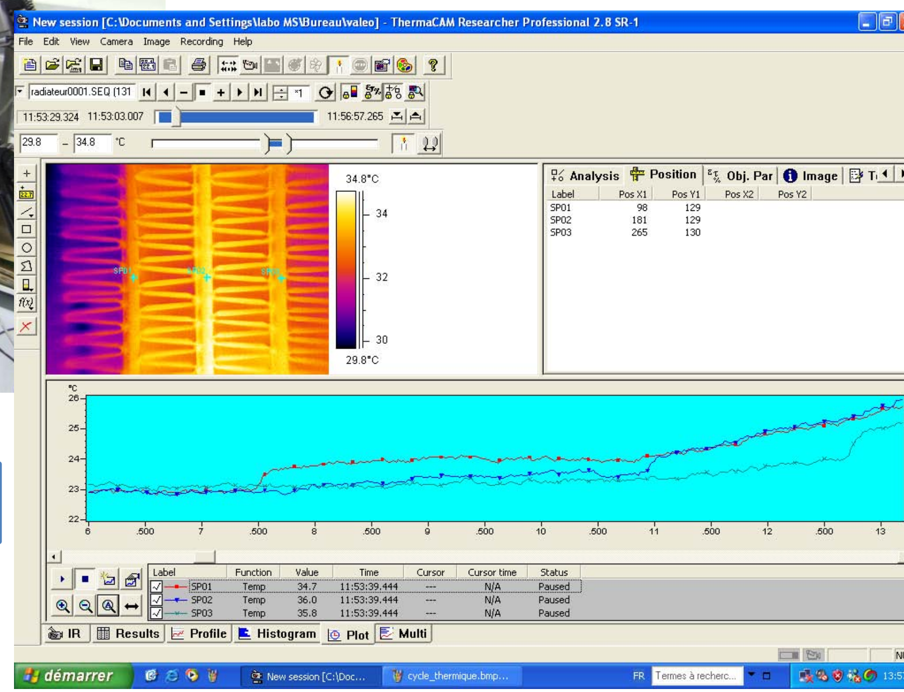
Thermal loading

Real thermal field



Fatigue experimental design



IR capture of selected points

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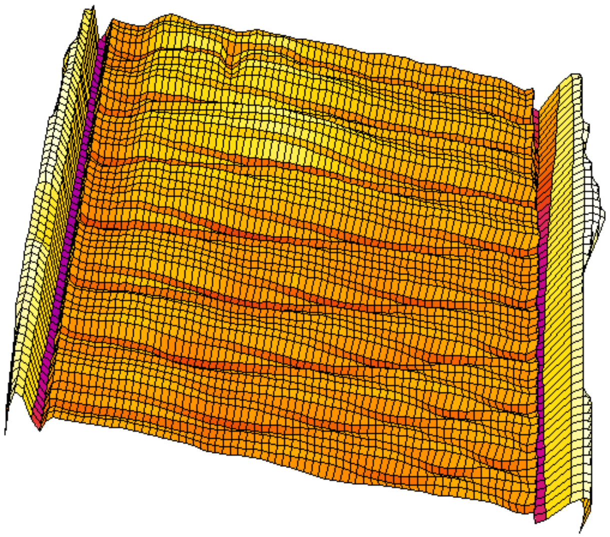
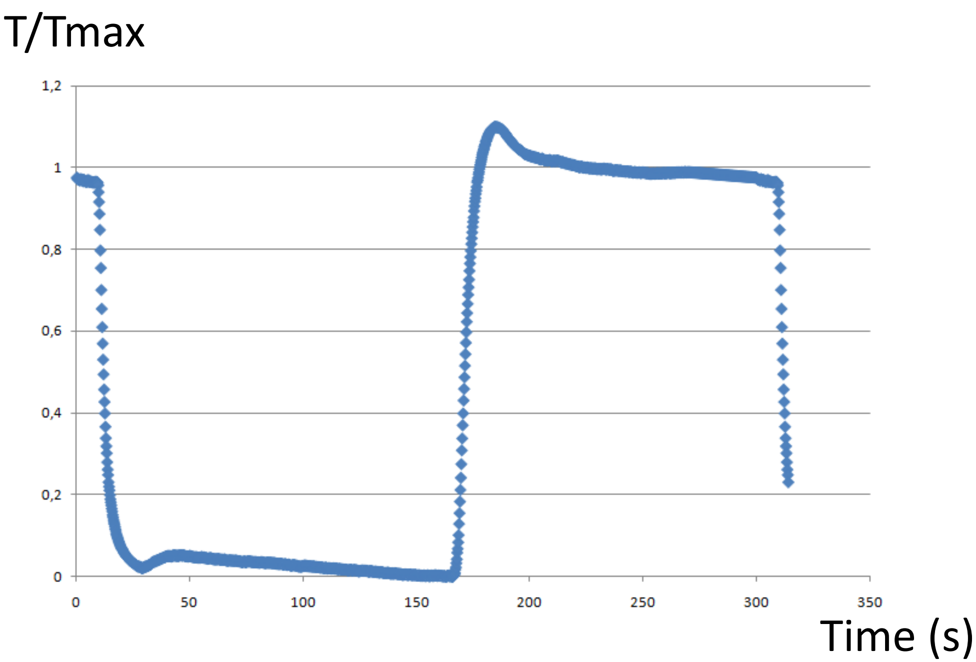
Thermal loading



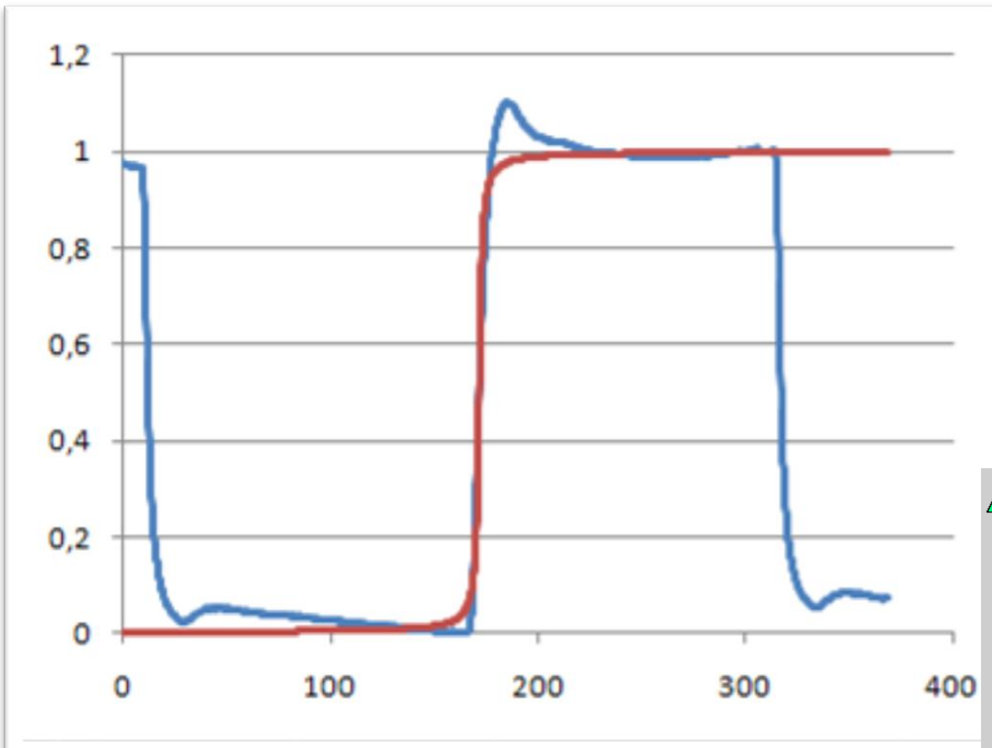
Thermal field in a U-shaped heat exchanger



Dimensionless temperature at the inlet

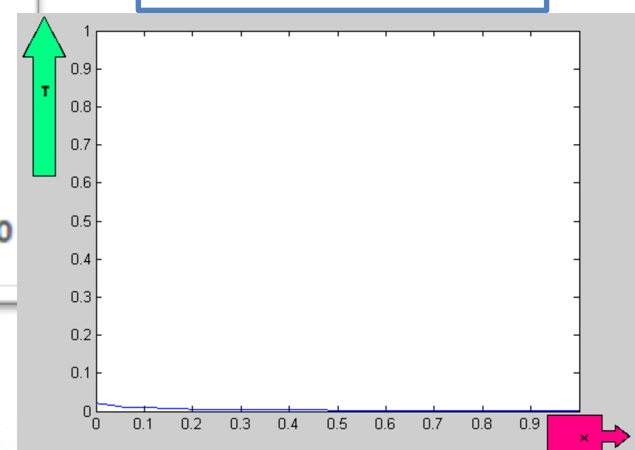
Thermal loading

2 ways in Comsol Multiphysics



As a function, entered as a table

As a trigonometric function, time dependant



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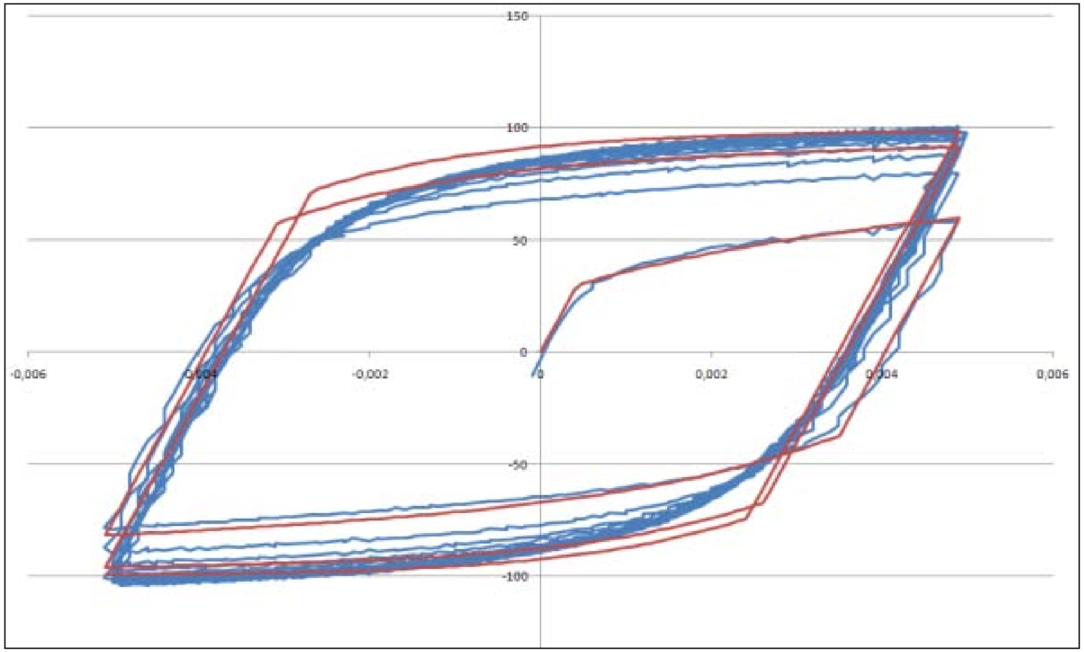
Mechanical behavior law

Follow damage → Plasticity

Fit cyclic tensile tests → Choice of hardening model



Cyclic tensile test

Mechanical behavior law

Chaboche Elastoplastic behavior law

Thermoelasticity with plastic strain

plastic strain time evolution

$$\dot{\varepsilon}_p = \frac{3}{2}\dot{p}\,\frac{\sigma' - X'}{J_2(\sigma - X)}$$

$$\begin{cases} \dot{X} = \frac{2}{3} C\,\dot{\varepsilon}_p - \gamma X \dot{p} \\ \dot{p} = \frac{1}{h} H(f) \left\langle \frac{3}{2} \frac{(\sigma' - X') : \dot{\sigma}}{J_2(\sigma - X)} \right\rangle \qquad h = C - \frac{3}{2}\gamma \frac{(\sigma' - X') : X}{J_2(\sigma - X)} + \mathrm{b}(\mathrm{Q} - \mathrm{R}) \\ R = Q(1 - \exp(-bp)) \\ J_2(\sigma - X) = \sqrt{\frac{3}{2}(\sigma' - X') : (\sigma' - X')} \end{cases}$$

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Mechanical behavior law

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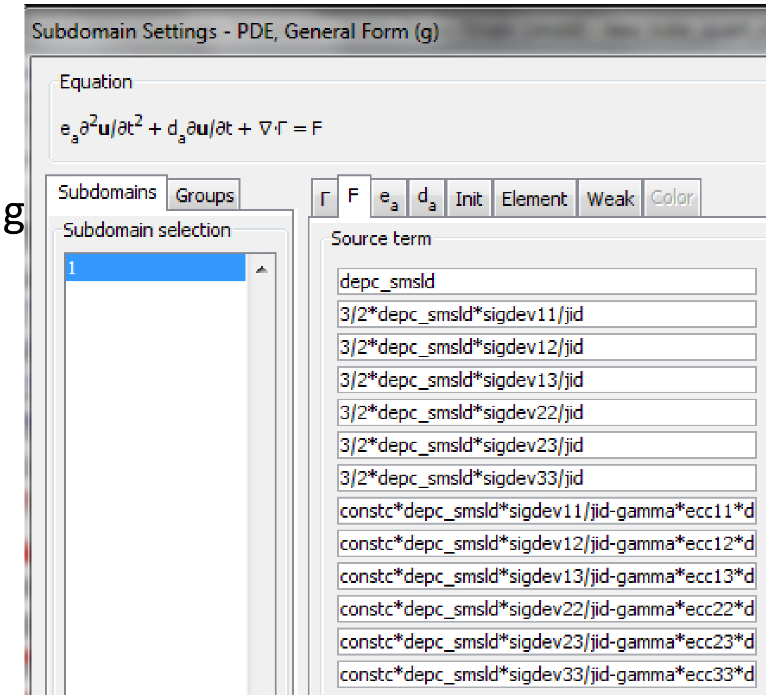
How to implement Chaboche Elastoplastic behavior law in Comsol Multiphysics

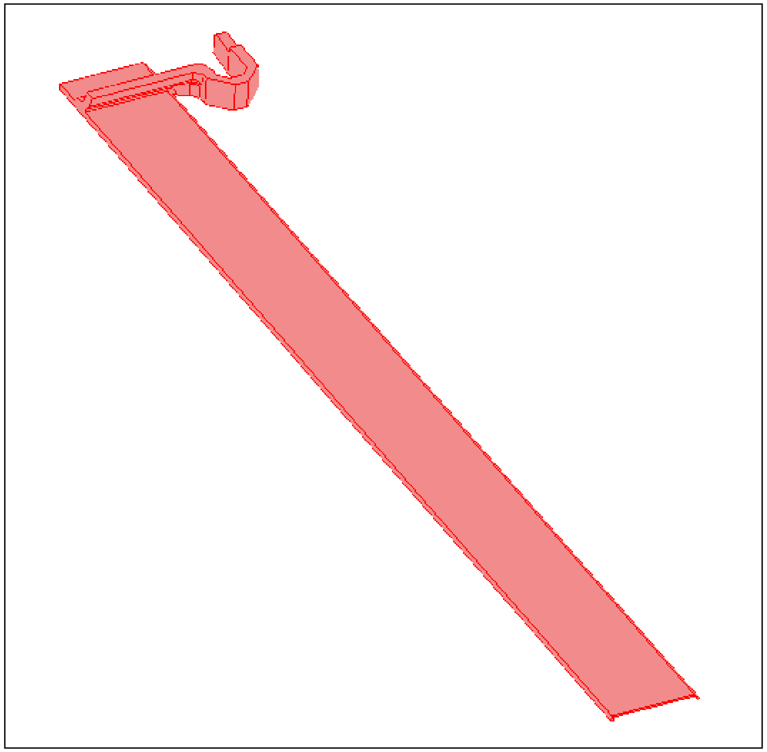
Use thermal structure module → T, elastic

PDE General form module → Solve hardening tensors



ThM modeling of the inlet critical zone

Quarter tube + collector



Thermal loading

Chaboche behavior

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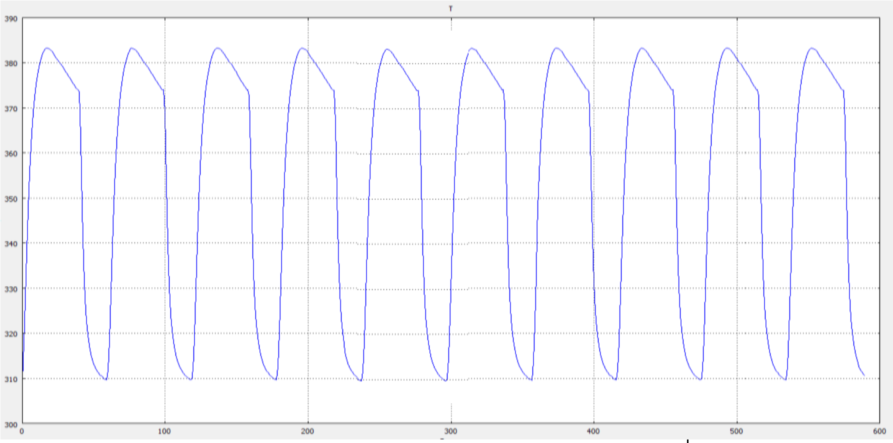
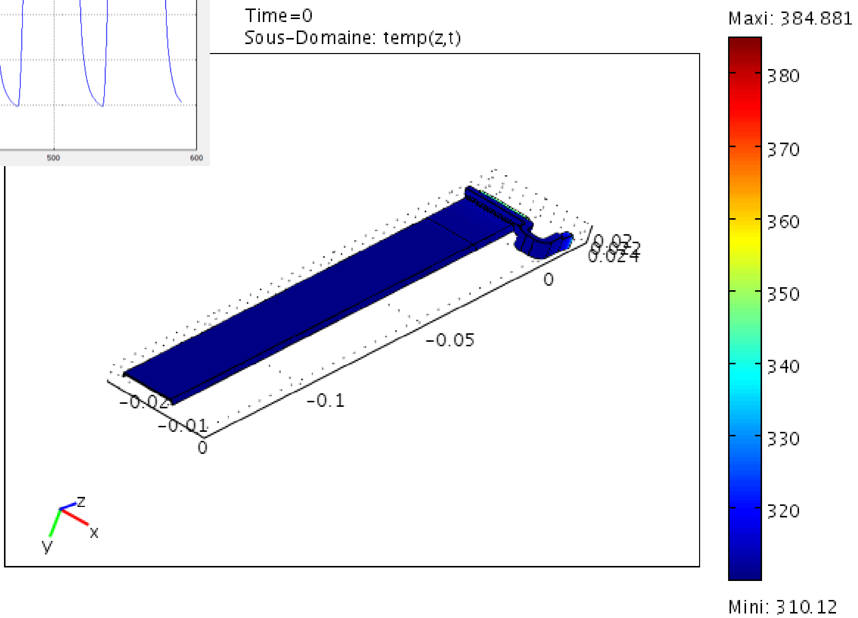
ThM modeling of the inlet critical zone

Thermal loading at the critical zone





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ThM modeling of the inlet critical zone

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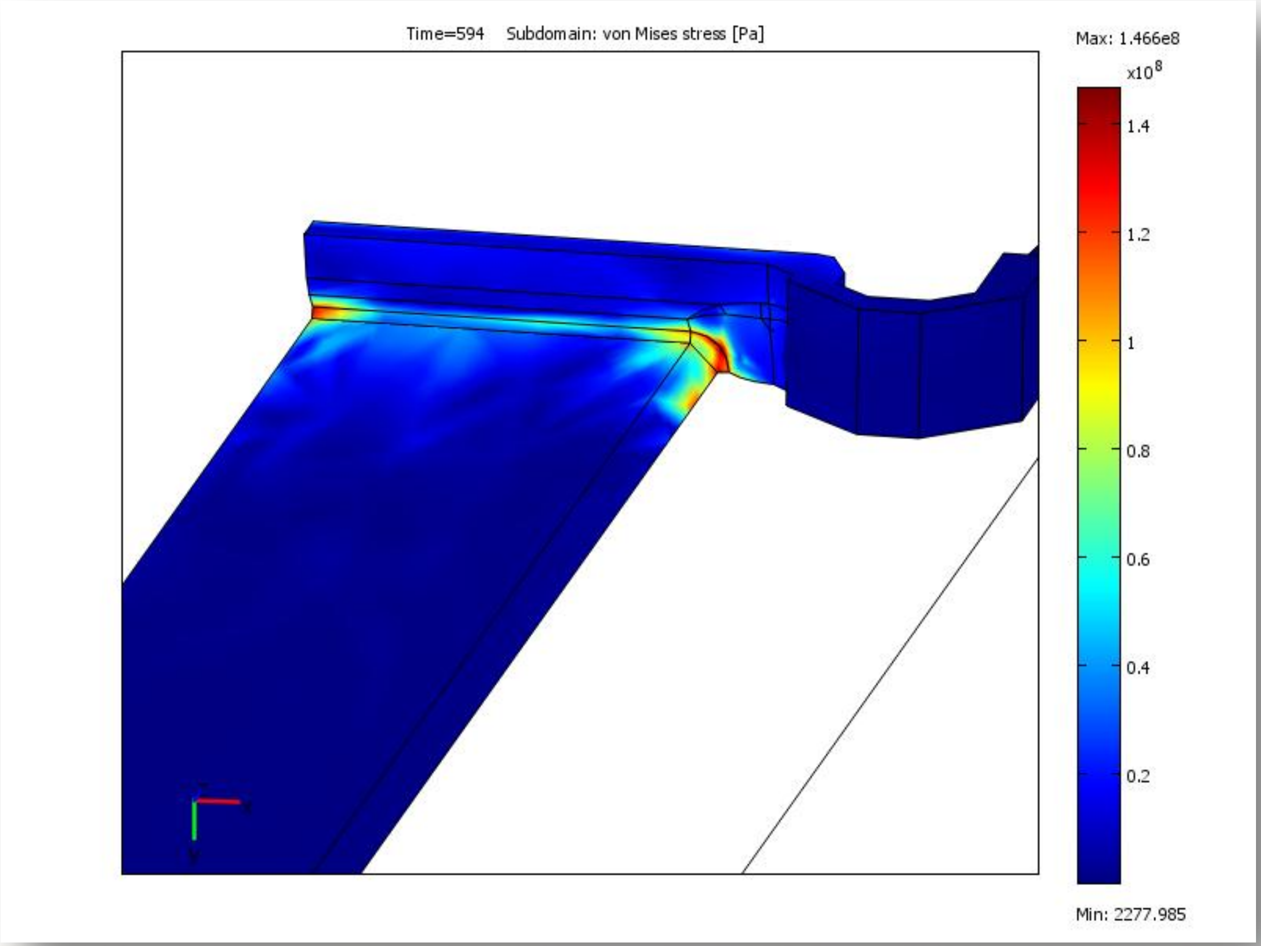
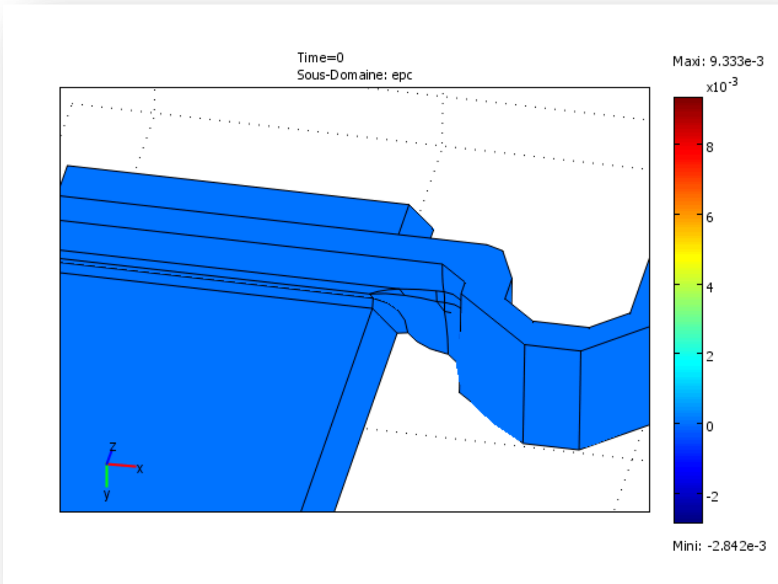
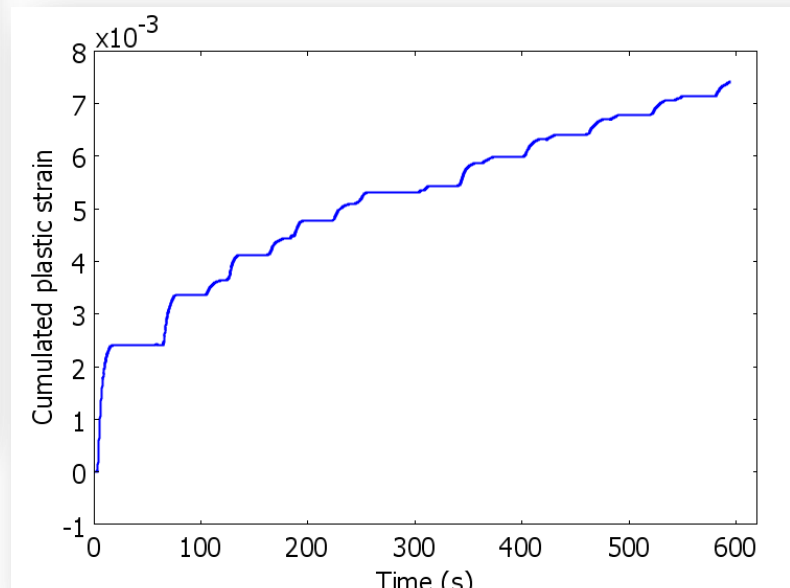
Residual stresses at the end of the 10th cycle



ThM modeling of the inlet critical zone

Cumulated plastic strain





ThM modeling of the inlet critical zone

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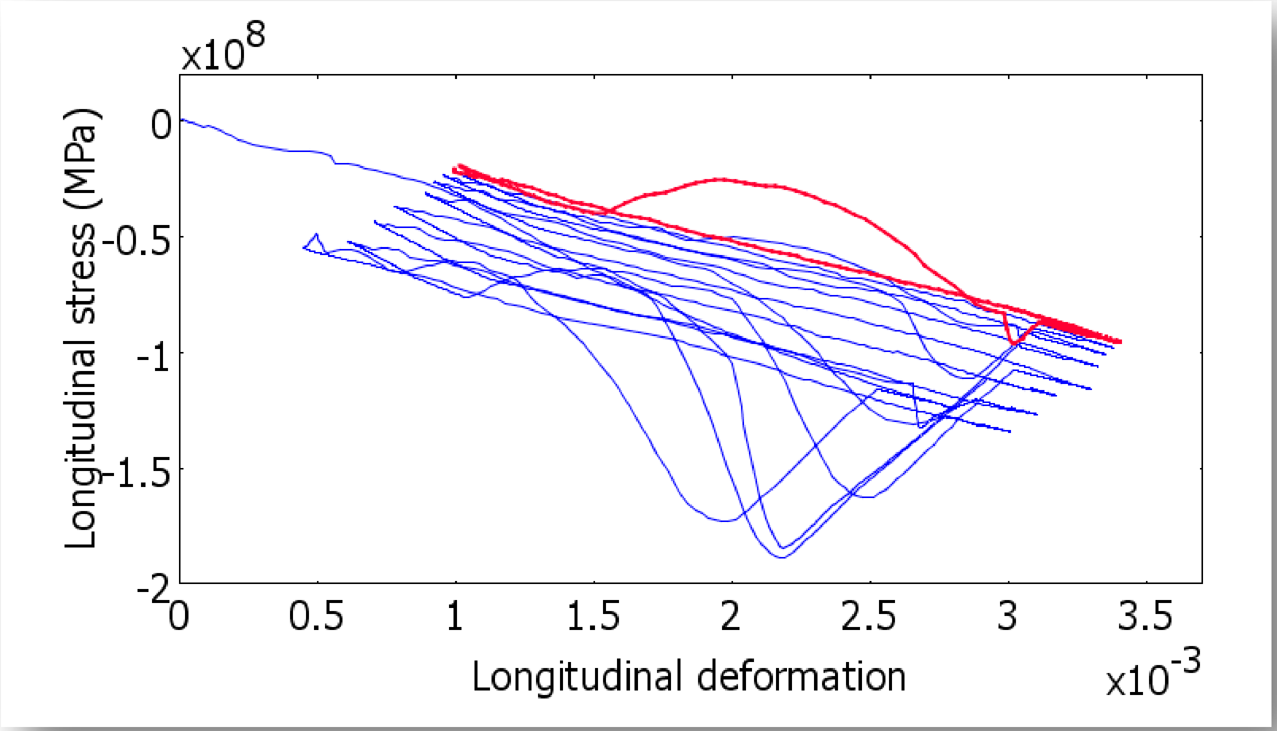
Cyclic stress vs strain



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ThM modeling of the inlet critical zone

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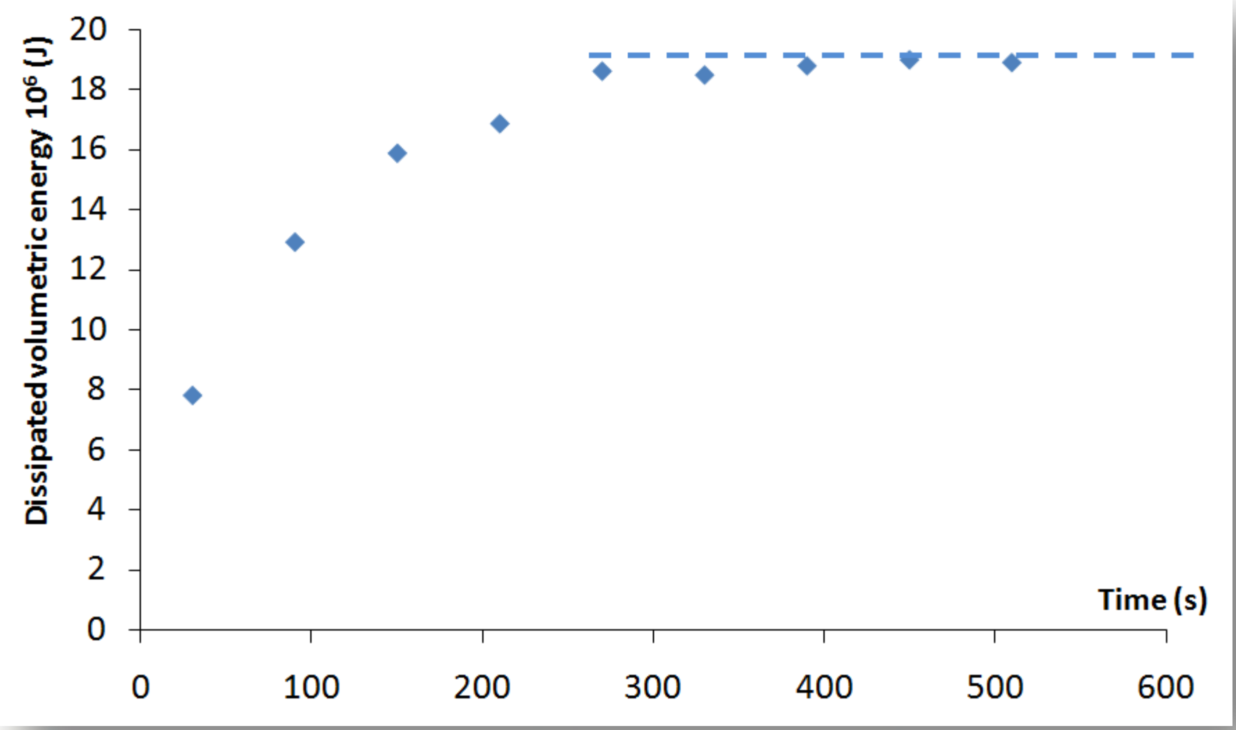
Energy based fatigue criterion

$$Wp = \int \sigma : \varepsilon_p \, dt$$



Conclusion

- Save time by entering thermal field
- Combined hardening model
- Good predictability
- Fatigue oriented design

Thankyou! Any questions...

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