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Effects of Convection on Experimental Investigation of Heat Generation During Plastic Deformation

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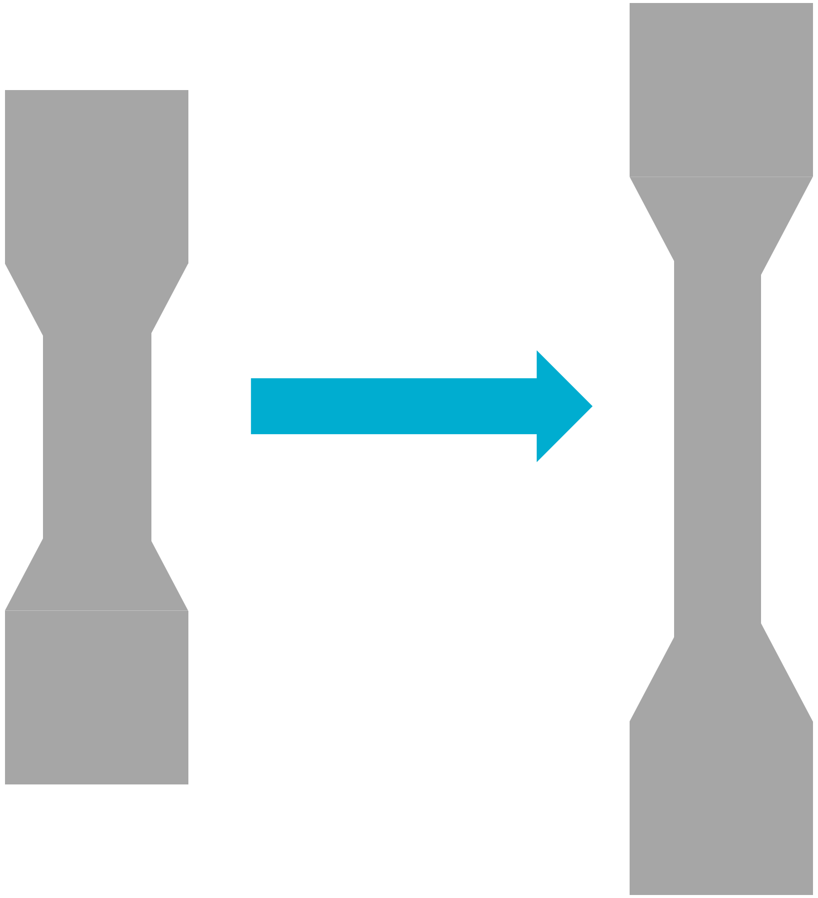
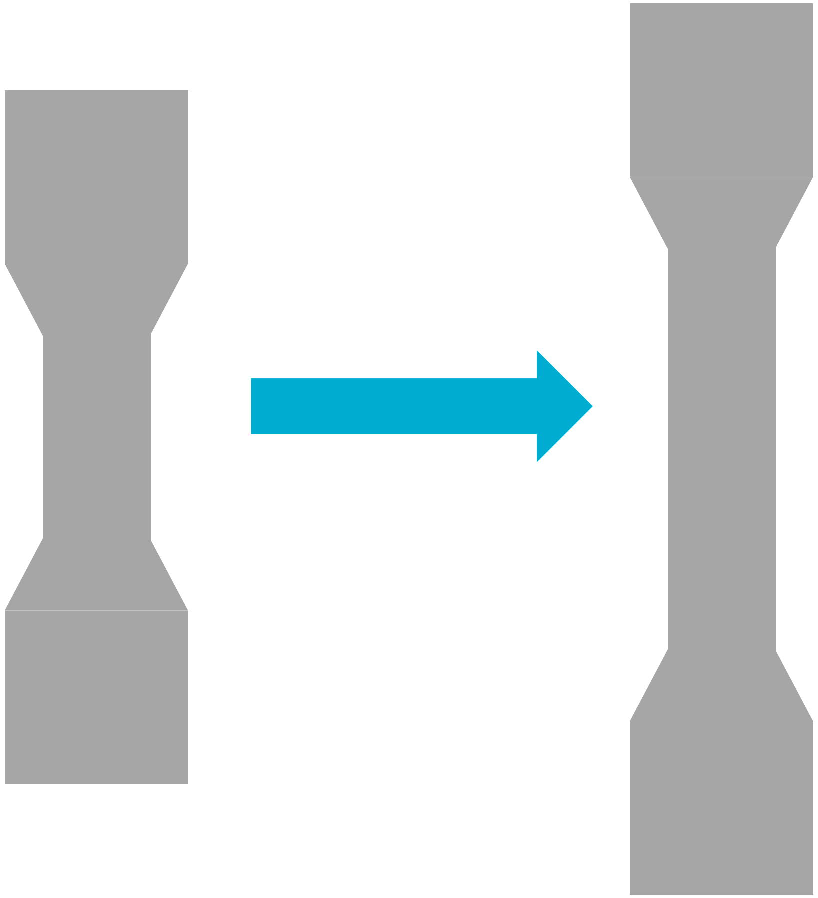
Introduction



As we apply strain, how much does the sample heat up?

Dependent on Quinney-Taylor coefficient, β

Introduction



As we apply strain, hot much does the sample heat up?

Dependent on Quinney-Taylor coefficient, β

NHTSA, 2015 Honda Fit Report

Introduction

$$\rho C_p \frac{\partial T}{\partial t} - k \frac{\partial^2 T}{\partial x^2} = Q_t^P + Q_t^e + r$$

Rosakis, P. et al. Journal of the Mechanics and Physics of Solids, 2000

Jones, A. et al. Tech Report, Sandia National Laboratory

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$$\rho C_p \frac{\partial T}{\partial t} - k \frac{\partial^2 T}{\partial x^2} = Q_t^P + Q_t^e + r$$

0 0

Plastic heating: $$Q_t^P = \beta W_t^P - \frac{A}{V}\left[h(T - T_\infty) + \sigma\varepsilon\left(T^4 - T_\infty^4\right)\right]$$

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$$\rho C_p \frac{\partial T}{\partial t} - k\frac{\partial^2 T}{\partial x^2} = Q_t^P + Q_t^e + r$$

$Q_t^e \to 0$, $r \to 0$

Plastic heating: $Q_t^P = \beta W_t^P - \frac{A}{V}\left[h(T - T_\infty) + \sigma\varepsilon\left(T^4 - T_\infty^4\right)\right]$

$h(T - T_\infty)$: convection

$\sigma\varepsilon\left(T^4 - T_\infty^4\right)$: radiation

β: Fraction of plastic work converted to heat

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convection radiation

Fraction of plastic work converted to heat

$$\beta = \frac{1}{W_t^P}\left[\rho C_p \frac{\partial T}{\partial t} - k\frac{\partial^2 T}{\partial x^2} + \frac{A}{V}\left[h(T - T_\infty) + \sigma\varepsilon(T^4 - T_\infty^4)\right]\right]$$

Small in many test conditions

Rosakis, P. et al. Journal of the Mechanics and Physics of Solids, 2000

Jones, A. et al. Tech Report, Sandia National Laboratory

Introduction

Determination of β - energy accounting problem

Accuracy in h determines accuracy in β

IRT and DIC determine temperature gradients

$$\beta = \frac{1}{W_t^P}\left[\rho C_p \frac{\partial T}{\partial t} - k\frac{\partial^2 T}{\partial x^2} + \frac{A}{V}[h(T - T_\infty)]\right]$$

Rosakis, P. et al. Journal of the Mechanics and Physics of Solids, 2000

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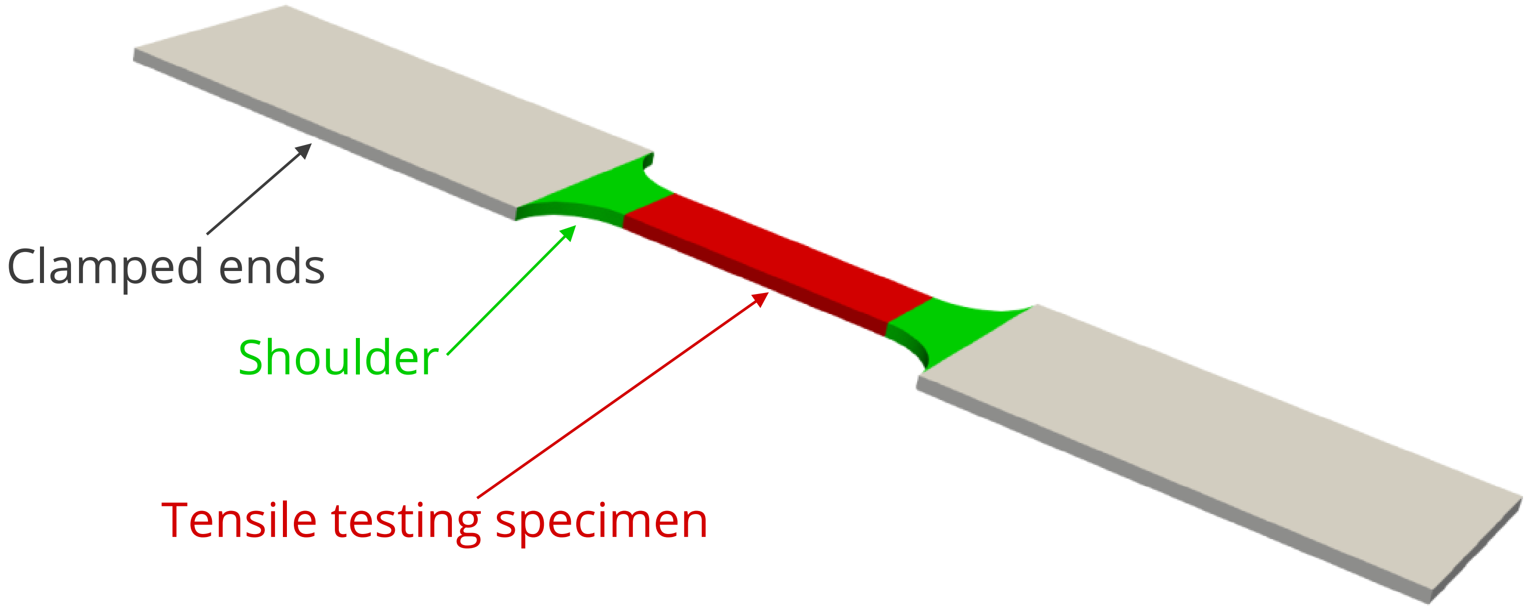
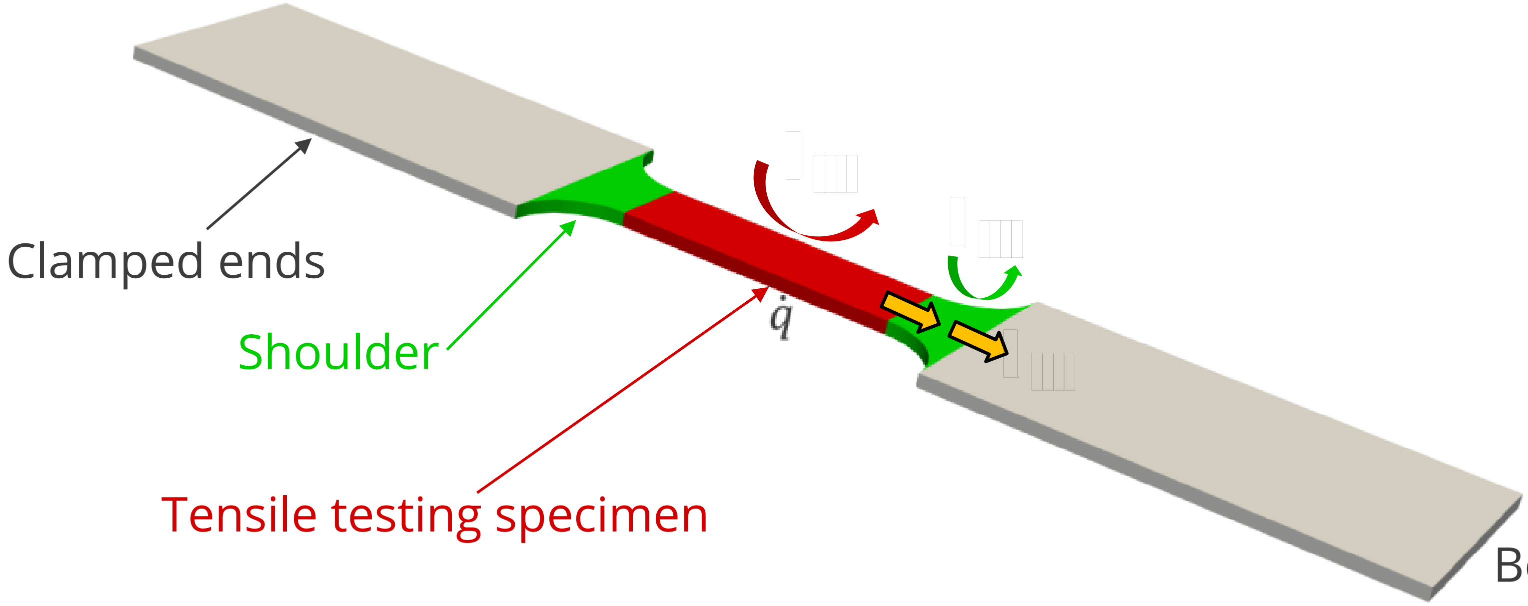
FEA model

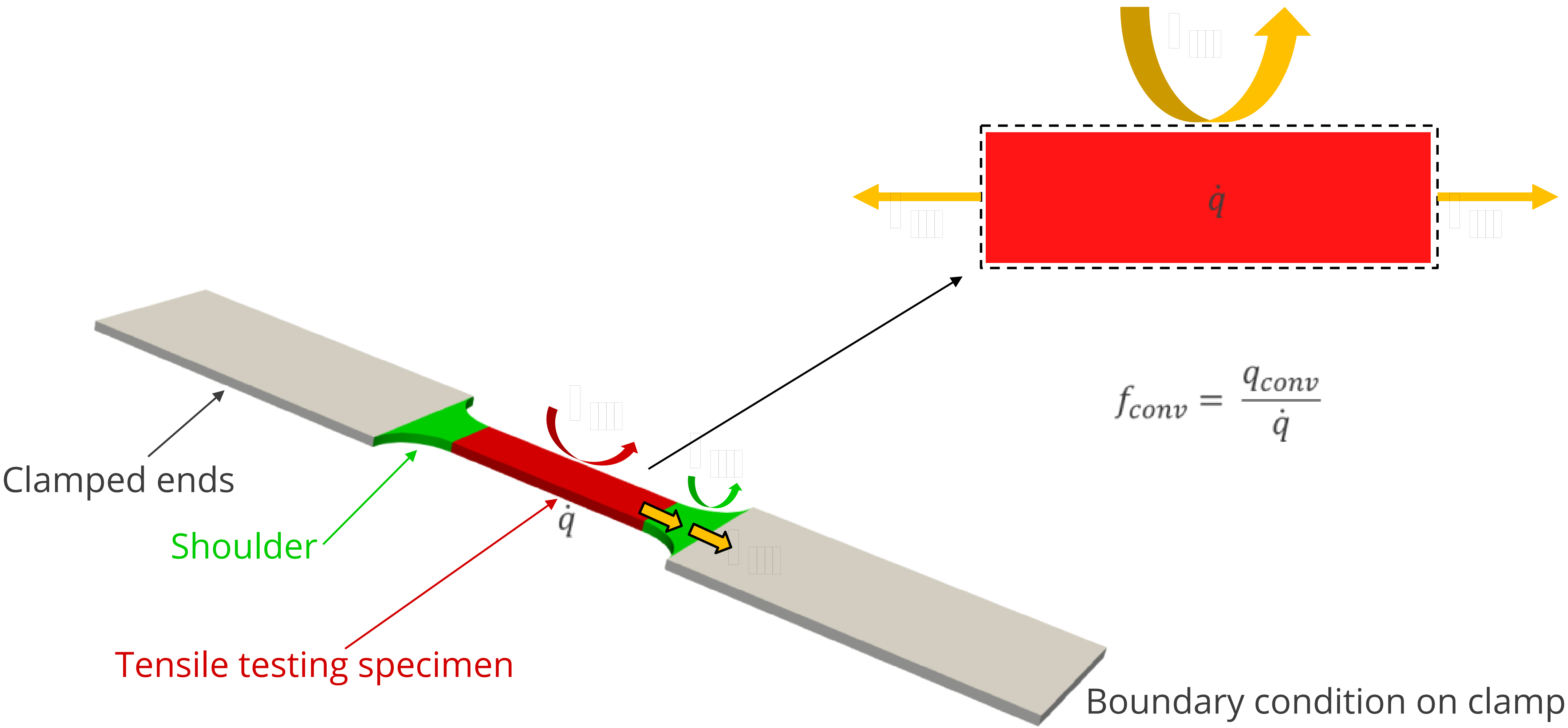


FEA model



Boundary condition on clamped ends: model as constant T or insulated

FEA model

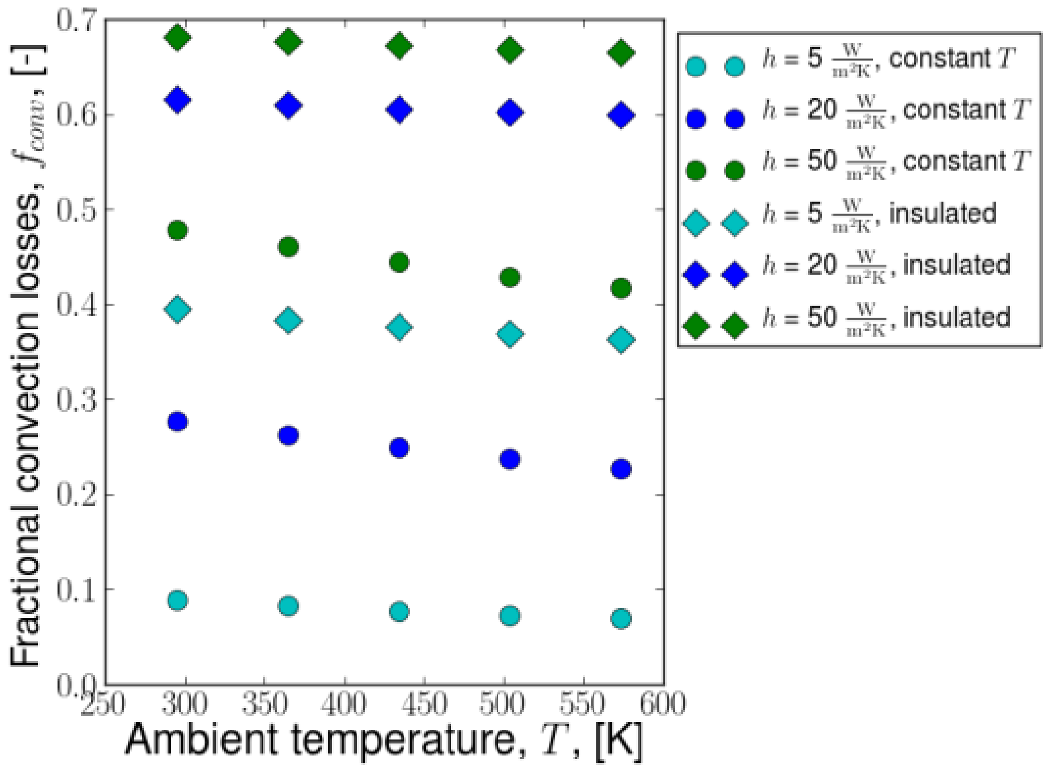


$$f_{conv} = \frac{q_{conv}}{\dot{q}}$$

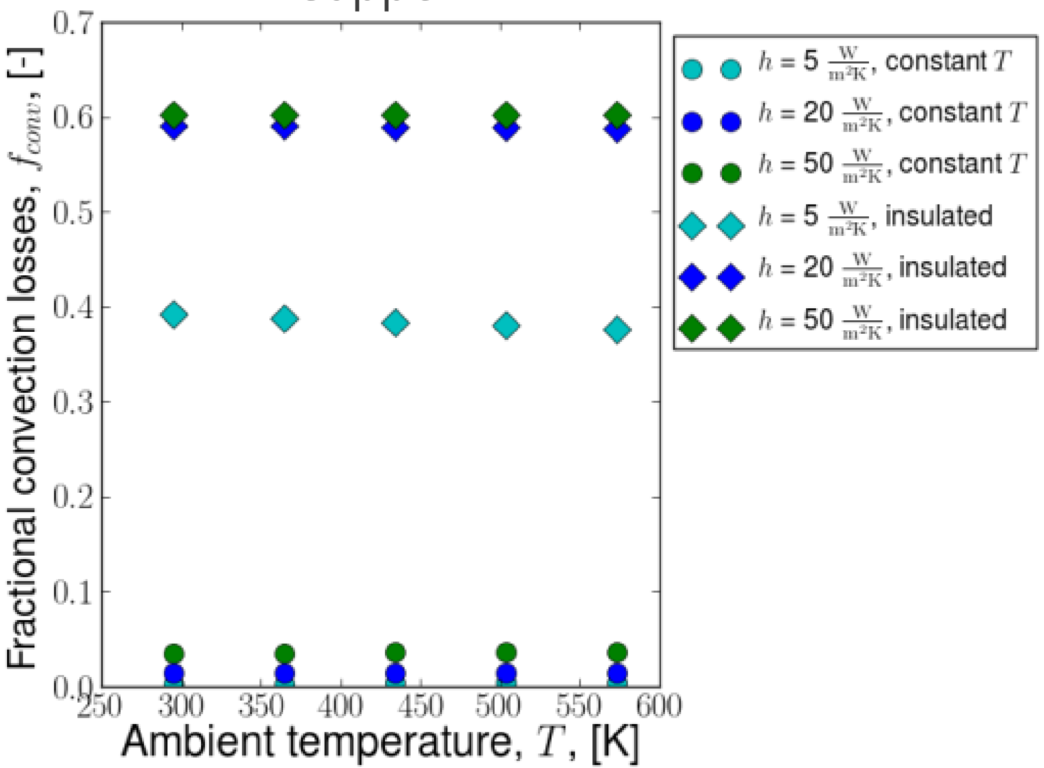
Boundary condition on clamped ends: model as constant T or insulated

Results – fractional convection losses

304L stainless steel



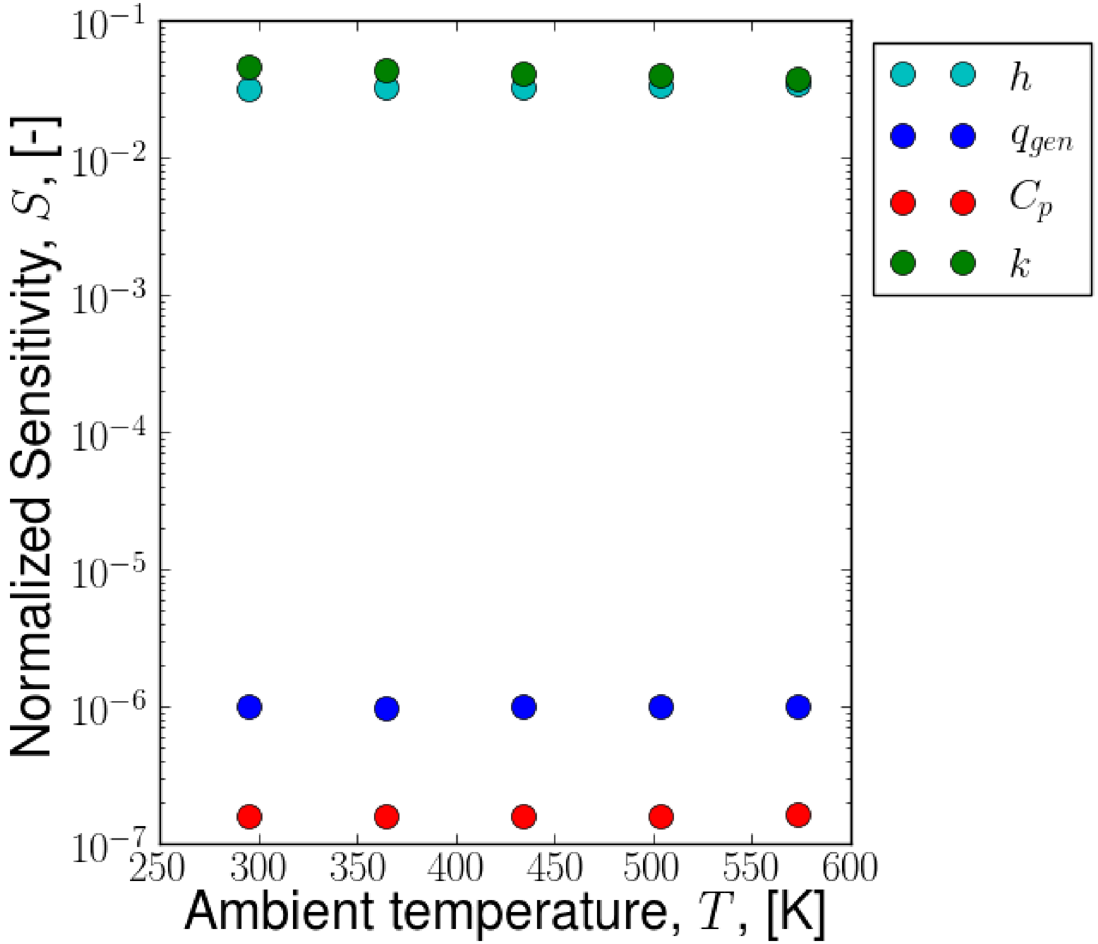
Copper



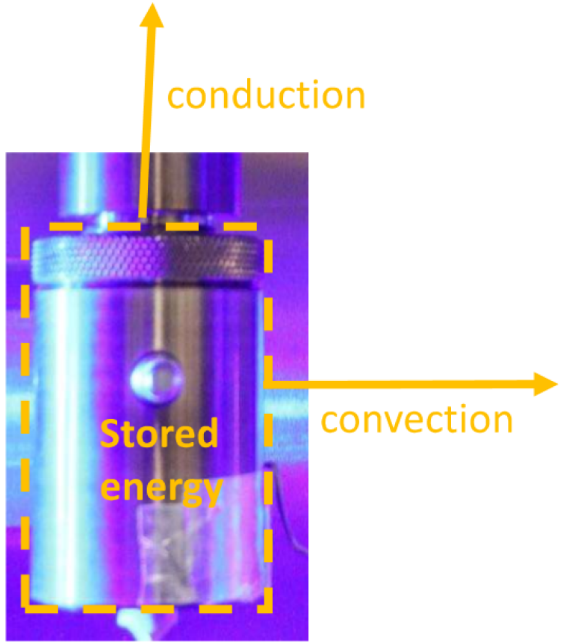
Results – sensitivity

$$S = \frac{1}{q_{conv}} \frac{\partial q_{conv}}{\partial p}$$

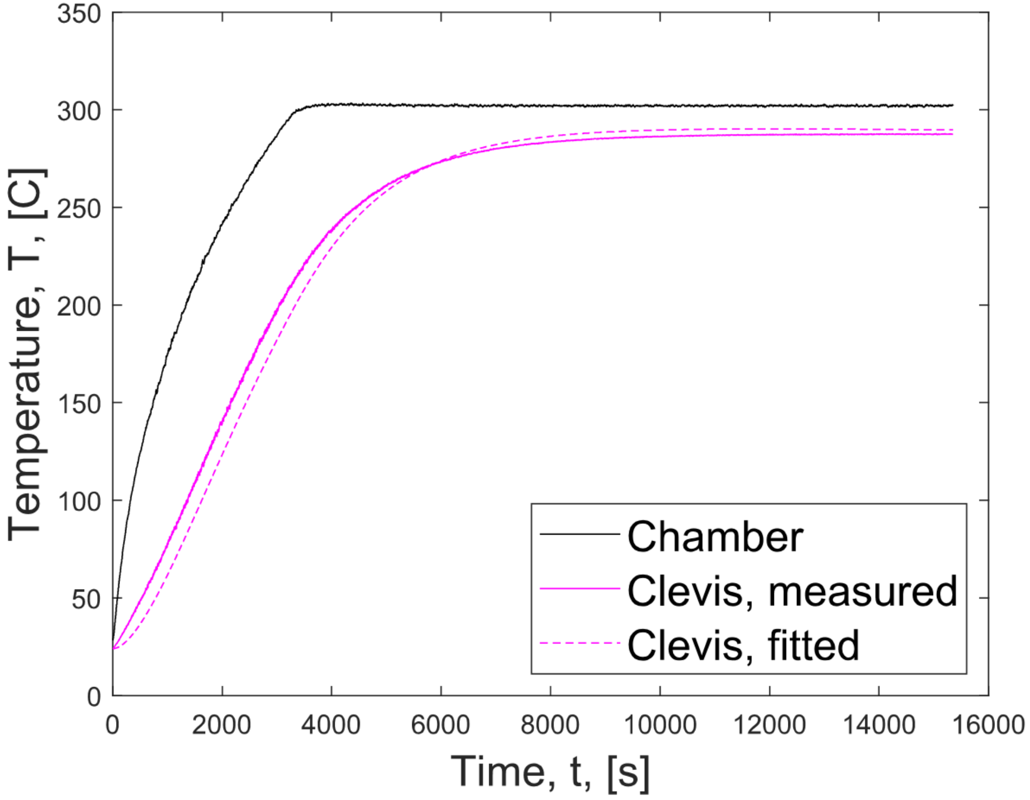
where p is a varied parameter



Results – convection coefficient fitting



$$h = 21.7 \, \frac{\mathrm{W}}{\mathrm{m^2K}}$$



Conclusions

Convection coefficient (h) plays a key role in ability to determine β

- High sensitivity to h and k
- ~70% variation in fractional convection losses in studied conditions

Radiation more significant in stainless steel

Convection coefficient in test chamber determined to be 21.7 $\frac{\mathrm{W}}{\mathrm{m^2K}}$