FIRE SPREAD SIMULATION

Sensitivity analysis of input parameters

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Part I: Introduction

Motivation

https://bit.ly/36UaNFo

http://bit.ly/3q2DhnD

Comprehensive pyrolysis models

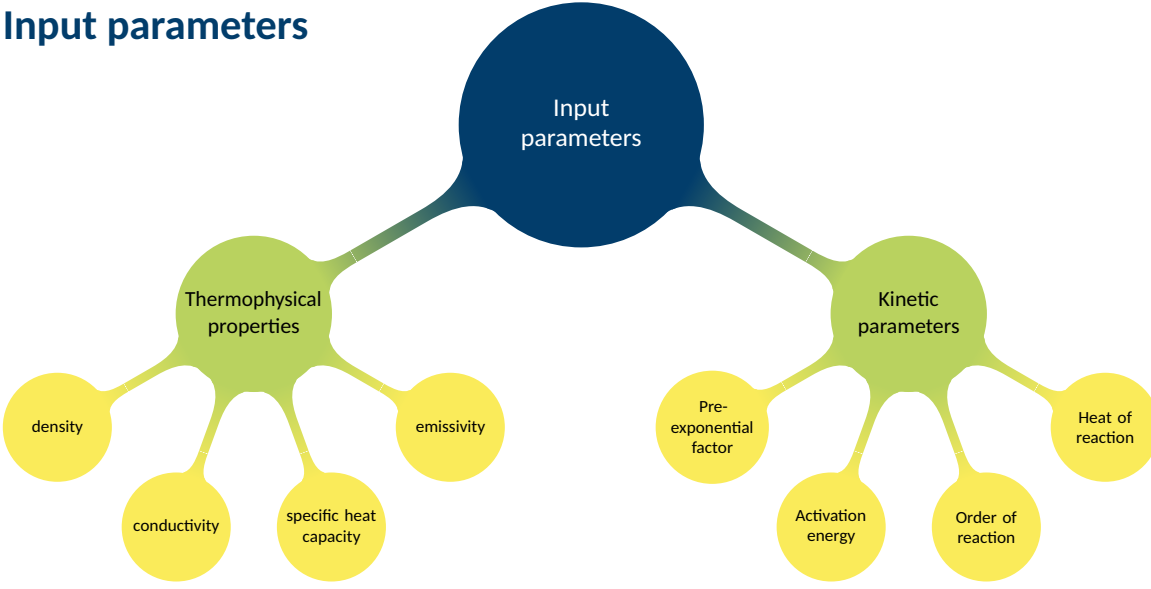
- Include chemical kinetics
- Increased accuracy
- Require many input parameters
  - Often not available
  - Difficult to determine
  - Not effective
- Fire Dynamics Simulator (FDS)

$$\rho_s c_s \frac{\partial T_s}{\partial t} = \frac{\partial}{\partial x}\left(k_s \frac{\partial T_s}{\partial x}\right) + \dot{q}'''_s$$

$$\dot{q}'''_{s,c}(x) = -\rho_s(0) \sum_{\alpha=1}^{N_m} \sum_{\beta=1}^{N_{r,\alpha}} r_{\alpha\beta}(x)\, H_{r,\alpha\beta}$$

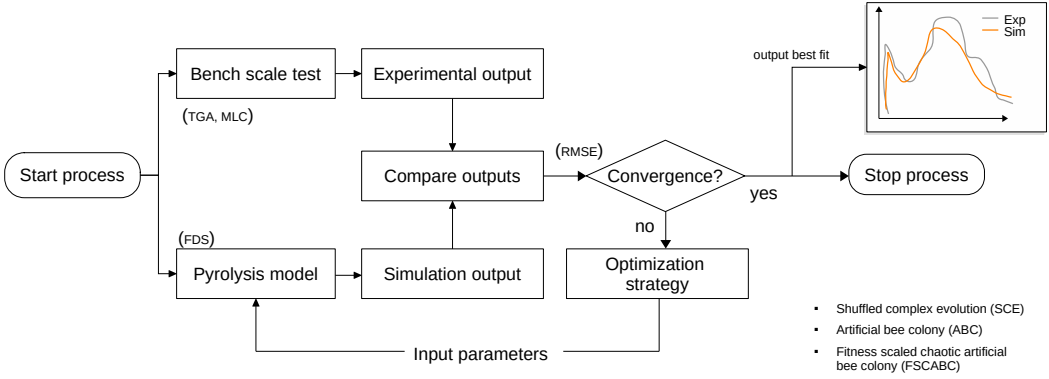
$$r_{\alpha\beta}(x) = \left(\frac{\rho_{s,\alpha}(x)}{\rho_s(0)}\right)^{n_{\alpha\beta}} A_{\alpha\beta} \exp\left(-\frac{E_{\alpha\beta}}{RT_s(x)}\right)$$

Input parameters



Inverse modelling and optimisation

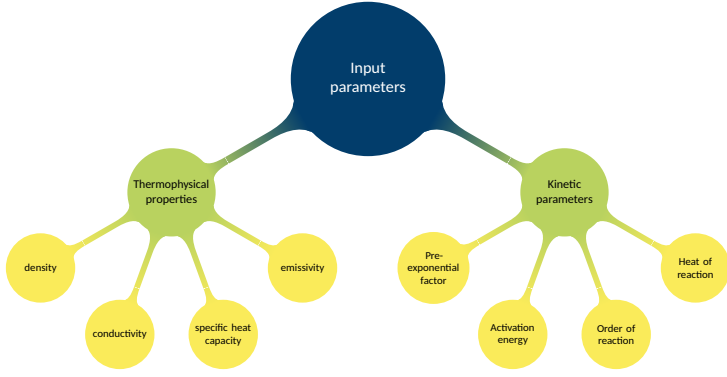
- Effective parameter set
- Computationally expensive



Adapted from: Lauer et al., 2016.

Why sensitivity analysis?

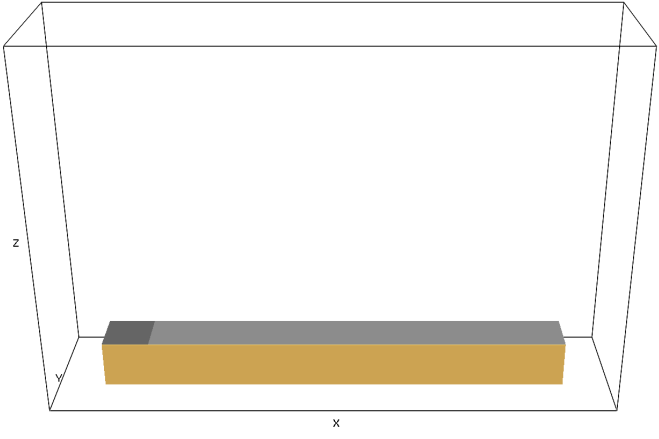
- Evaluate function response to changes in input variables
- High dimensional data
- Filter out irrelevant variables
- Retain important variables



Part II: Methodology

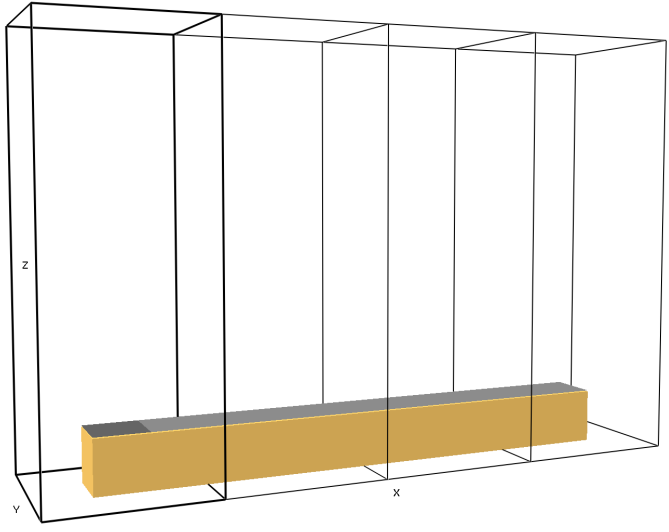
Simulation set-up

- Artificial solid material
- External heat flux: 25 kW
- 5 different reactions
- 27 parameters



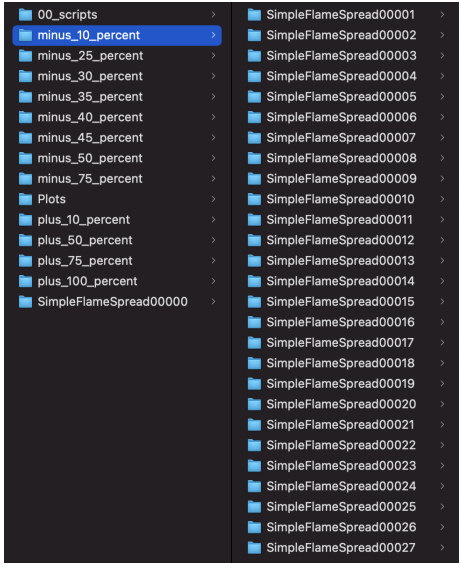
Simulation set-up

- FDS version: 6.7.6-618
- Horizontal slab: 110 x 10 cm
- Domain: 120 x 30 x 80 cm
- Mesh refinement: 2 x 2 x 2 cm



Local sensitivity analysis

- Simplified screening
  - -10%, -50%, -75%
  - +10%, +50%, +75%, +100%
  - -25%, -30%, -35%, -40%, -45%
- One-factor-at-a-time approach
- 1 simulation = 1 parameter varied



Local sensitivity analysis

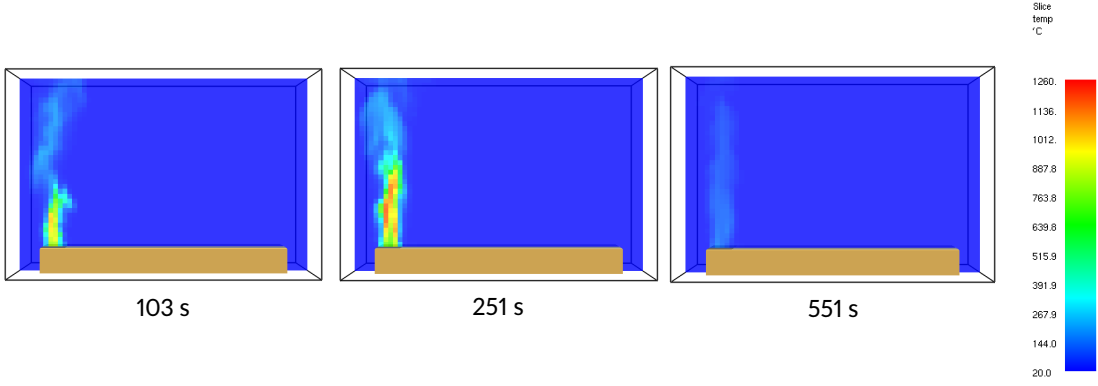
- Simulation responses in terms of:
  - Heat release rate (HRR)
  - Mass loss rate (MLR)
- Root mean square deviation (RMSD)
- Deviations refer to the original set of parameters

$$\mathrm{RMSD} = \sqrt{\frac{1}{n}\sum_{i=1}^{N}(y_i - \hat{y}_i)}$$

Part III: Results

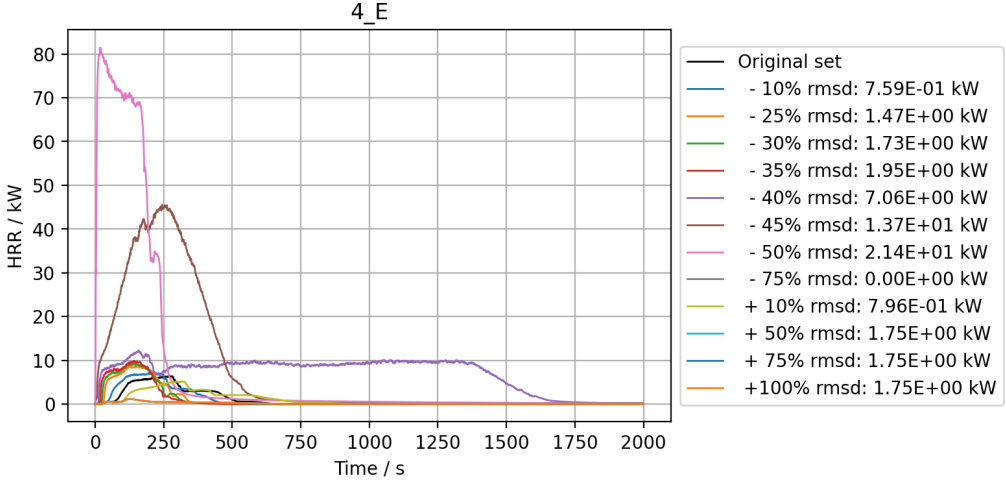
Preliminary results

- Original parameter set: no flame spreading



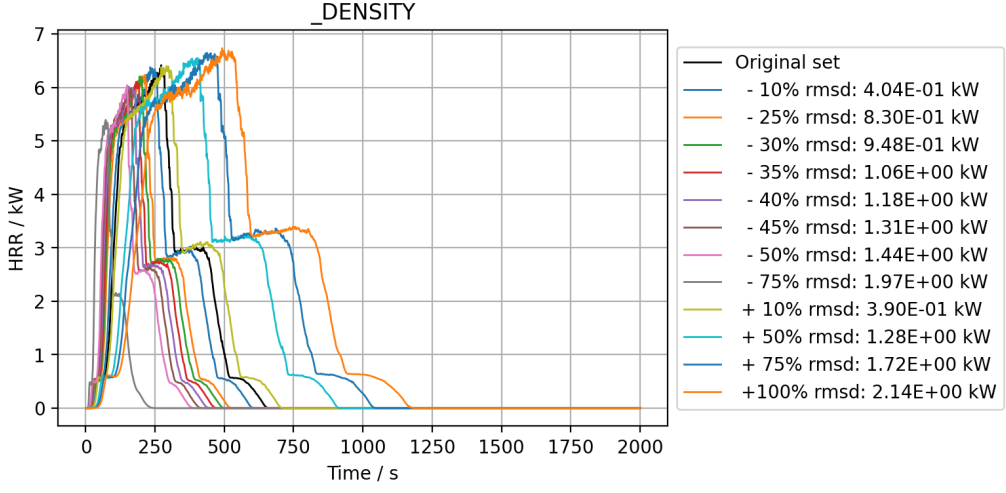
Preliminary results: effect on HRR

- Activation energy of 4^{th} reaction



Preliminary results: effect on HRR

- Density



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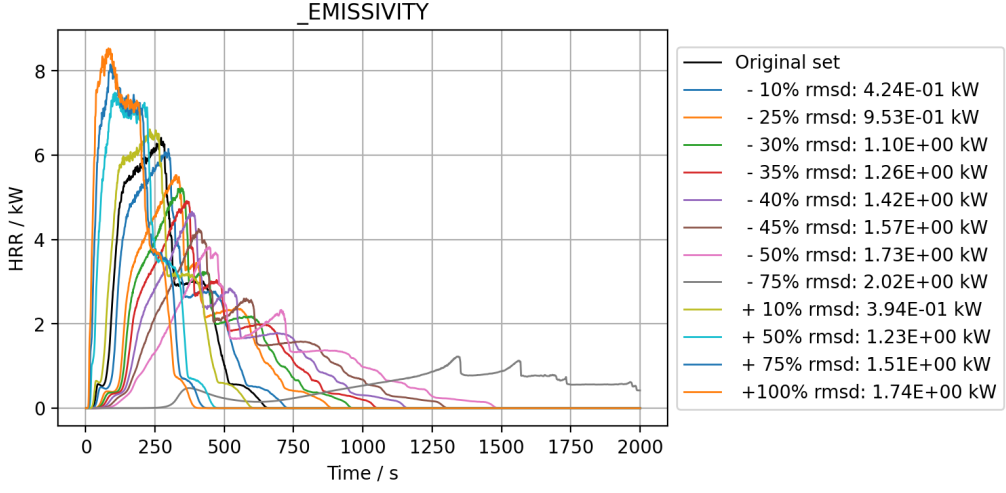
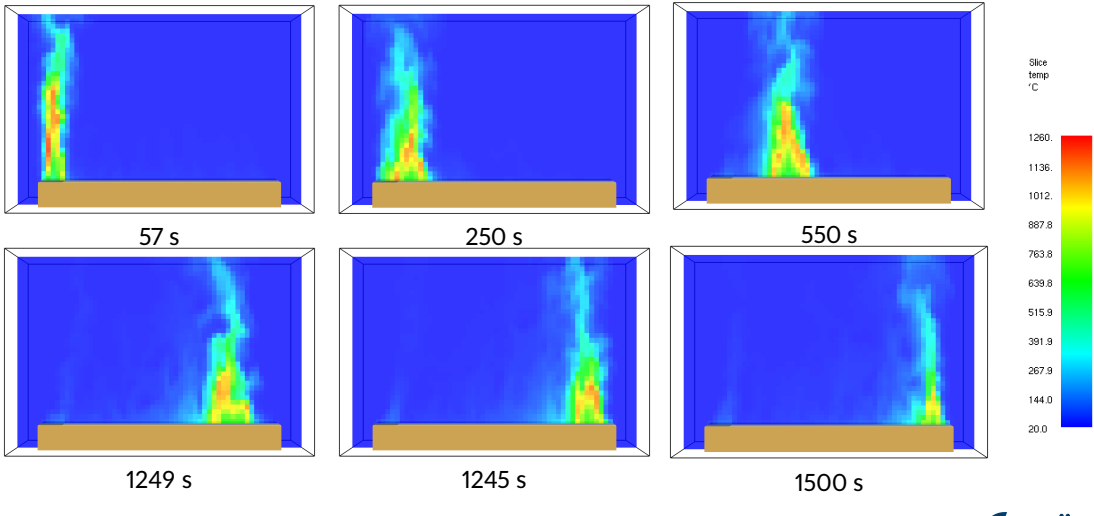
Preliminary results: effect on HRR

- Emissivity



Preliminary results

- Activation energy of 4^{th} reaction varied at -40%: flame spreads



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Part IV: Remarks and upcoming work

Remarks and upcoming work

- Within the current variation range (-75% to +100%), **flame spread** is mostly affected by the **activation energy of the 4th reaction**;
- Actual flame spread occurs for changes of -40 - -45% in activation energy of the 4th reaction;
- Flame spread can still respond to larger changes in other parameters;
- The one-at-a-time approach is limited, as responses to simultaneous changes in two or more parameters cannot be evaluated;
- The number of input parameters should be reduced before considering global sensitivity analyses methods;
- Future set-ups should cover different sample sizes and orientations, as well as try to reproduce or be compared to experimental data.

Thank you!

Questions?