Uncertainties in material thermal modelling of fire resistance tests

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ABSTRACT

The FIRETOOLS project will provide tools to obtain the fire properties of building products and constructions on a continuous scale by means of the material data of which they are composed. An important factor is the input parameters. In this contribution the influence of the uncertainties in material properties and boundary parameters on a one-dimensional heat transfer model is investigated. Probability functions are assigned to input parameters and the predicted temperature of the unexposed side is compared with experimental results of gypsum plasterboard exposed to the ISO 834 standard fire curve.

NUMERICAL MODEL

A code for computing one dimensional transient heat conduction through the material is written in MATLAB®. Convective and radiative boundary conditions are applied to both sides. A sensitivity study is performed with the maximum and minimum values of each input parameter.

Sensitivity: Material Properties

Table 1: Material Properties

Property	Probability Function (min-max)	Fixed Value
$k_{eff\ amb.}$ [W/(mK)]	0.18 – 0.3	0.22
$C_{p\ gasb}$ [kJ/(kg/K)]	20 – 30	25
ρ_{eff} [kg/m³]	820 – 860	840

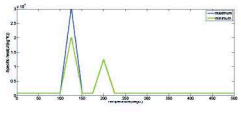

Figure 2: Thermal Conductivity GPB

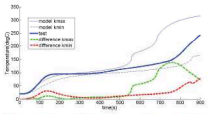

Figure 3: Sensitivity Thermal Conductivity

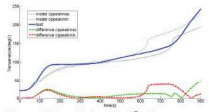

Figure 4: Sensitivity Specific Heat

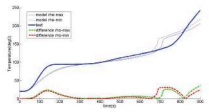

Figure 5: Sensitivity Density

Sensitivity: Boundary Parameters

Table 2: Boundary Parameters

Property	Probability Function (min-max)	Fixed Value
$h_{c\ hot}$ [W/(m² K)]	20 – 60	25
$h_{c\ cold}$ [W/(m² K)]	4 – 10	4
T_{cold} [K]	288 – 298	293
ε_{hot} [-]	0.8 – 1.0	0.9
ε_{cold} [-]	0.8 – 1.0	0.9

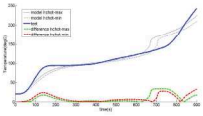

Figure 7: Sensitivity h_c Hot Side

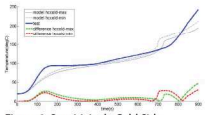

Figure 8: Sensitivity h_c Cold Side

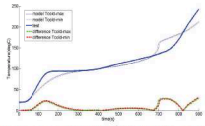

Figure 6: Sensitivity Ambient Temperature

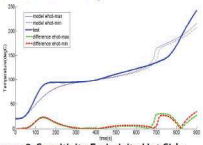

Figure 9: Sensitivity Emissivity Hot Side

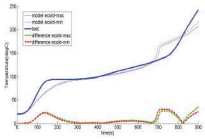

Figure 10: Sensitivity Emissivity Cold Side

Functional Analysis

Quantitative comparisson of the results is provided by functional analysis, where the data is treated as a vector. The difference between the time series can be characterize by the distance and the angle between the vectors.

- ERD : distance
- EPC : shift
- SC : shape curves

$$ERD = \frac{\|T_{max}\text{-}T_{min}\|}{\|T_{max}\|}$$

$$EPC = \frac{\langle T_{max},\ T_{min}\rangle}{\|T_{min}\|^2}$$

$$SC = \frac{\langle T_{max},\ T_{min}\rangle}{\|T_{max}\|\|T_{min}\|}$$

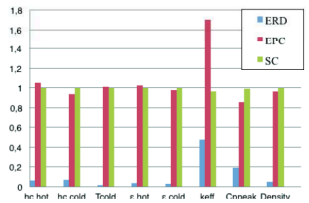

Figure 11: Functional Analysis

MONTE CARLO

The sensitivity to the uncertainties in multiple input parameters is studied with a Monte Carlo approach. The uniform probability distributions shown in Table 1-2 are used for the input parameters.

All Input Parameters Varied

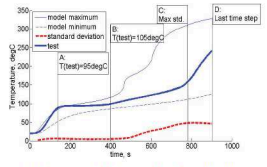

Figure 12: Maximum and Minimum Modelling Results

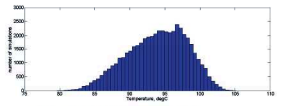

Figure 13: Distribution results at A

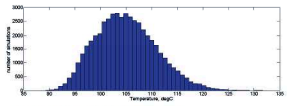

Figure 14: Distribution results at B

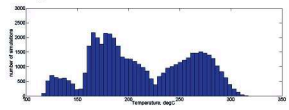

Figure 15: Distribution results at C

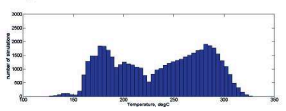

Figure 16: Distribution results at D

Several Parameters Varied

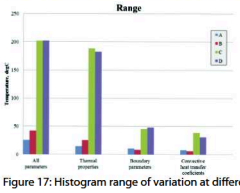

Figure 17: Histogram range of variation at different times

CONCLUSIONS

The model is more sensitive to thermal properties rather than boundary parameters, especially to thermal conductivity. The variability of the results is relatively low up until the end of the "water plateau". The model is less sensitive to the uncertainties until this point. The conclusions are valid for materials with similar level of uncertainties in the thermal properties and boundary parameters. Convective heat transfer coefficient is the most uncertain of the boundary parameters and requires further investigation for modelling purposes.

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