One-dimensional transient pyrolysis model for intumescent fire-retardant polymers usage in Electric Vehicle battery pack applications: validation with fire-retarded polycarbonate

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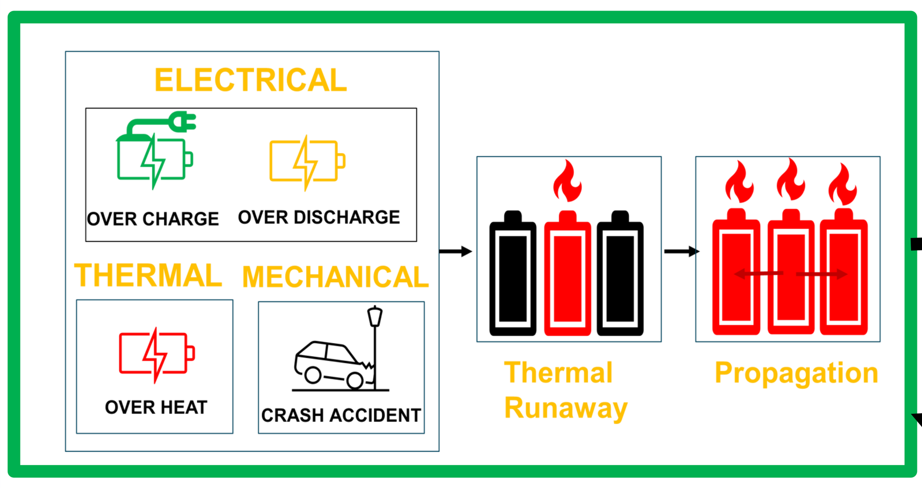
CONTEXT & OBJECTIVES

CONTEXT



- Formulate new fire-retardant solution
- Assess capability
- Passing regulatory testing (for safety and compliance)

Insulation to delay fire propagation

Experiment
- Expensive, material loss and dangerous conditions

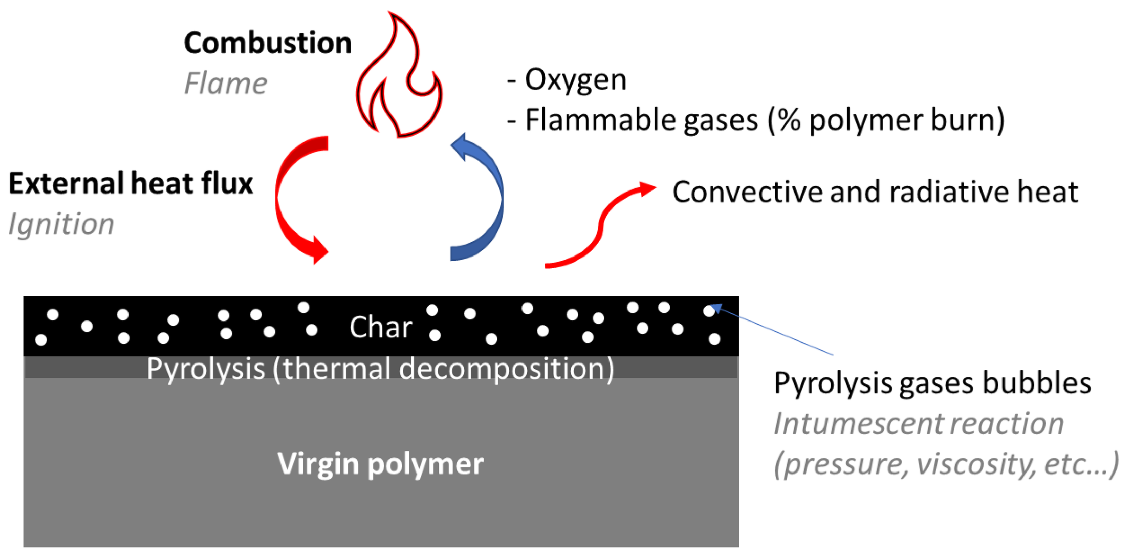
Model
- Time and money saving
- Less risk

OBJECTIVES

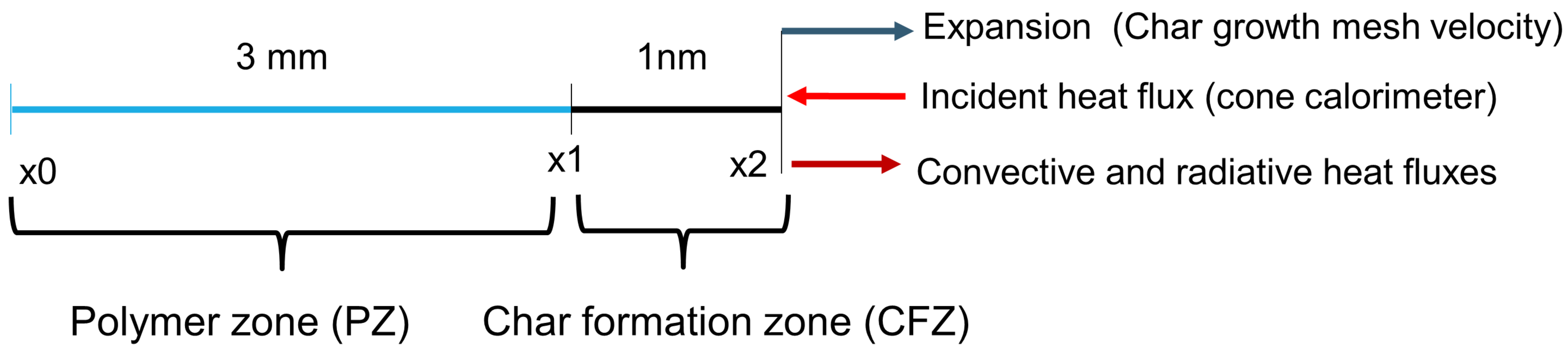
- Built pyrolysis models
- Predicted different fire scenarios

PYROLYSIS MODEL

Cone calorimeter (50kW/m²)



Model



GOVERNING EQUATIONS

$$\text{IFR PP} \xrightarrow{\text{Heat}} \alpha * \text{Gases} + (1-\alpha)\text{Char}$$

Polymer consumption

$$\frac{\partial C_p}{\partial t} = -k_0 * C_p$$

Mass conservation

$$\frac{\partial C_i}{\partial t} - D_i.\frac{\partial^2 C_i}{\partial x^2} = f$$

$i = PZ$ and $f = \Delta H_0 * k_0 * C_p$
$i = CFZ$ and $f = 0$

Heat transfer

$$\rho_i * Cp_i \frac{\partial T}{\partial t} - k_i \frac{\partial^2 T}{\partial x^2} = F$$

$i = PZ$ and $f = \alpha * k_0 * C_p$
$i = CFZ$ and $f = 0$

Implemented in COMSOL® Multiphysics

ASSUMPTIONS

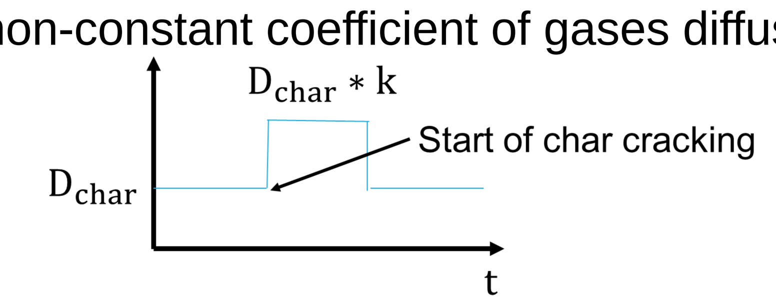
- Constant volume for PZ and moving boundary for the intumescence behaviour

$$\text{mvel} = \frac{(1-\alpha) * \chi}{\rho_{\text{char}}} * \left(-\frac{\partial C_p}{\partial t}\right)$$

- Additional and non-constant heat flux on the material surface: thermal expansion

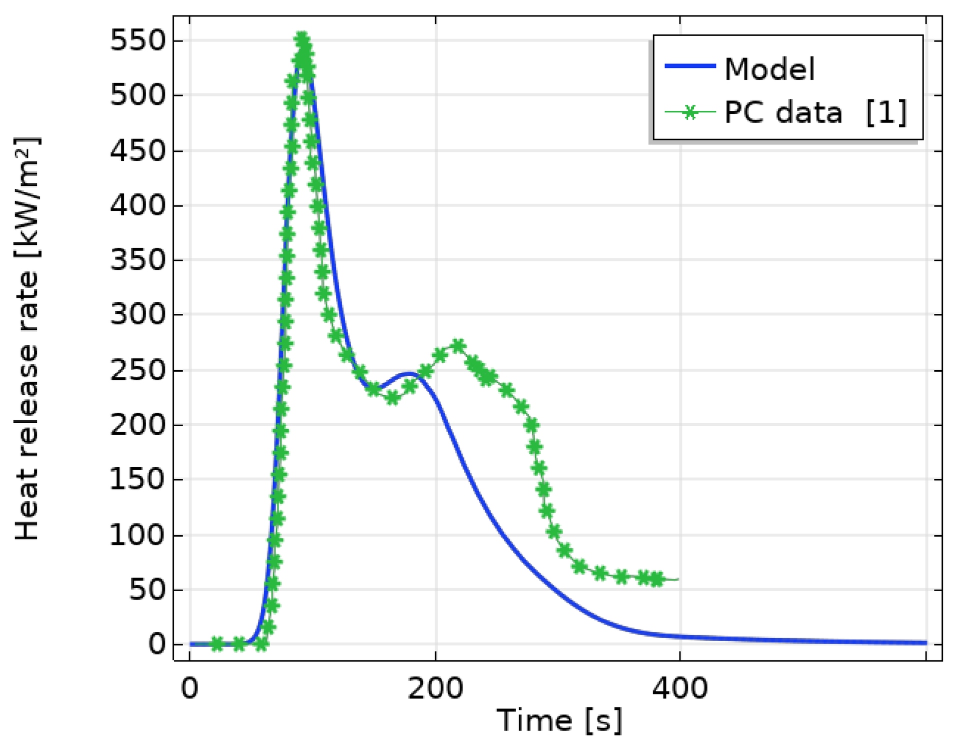
$$Q_{\text{add}} = \frac{Q_{\text{cone}} * t}{t_{\text{comb}}} + Q_i$$

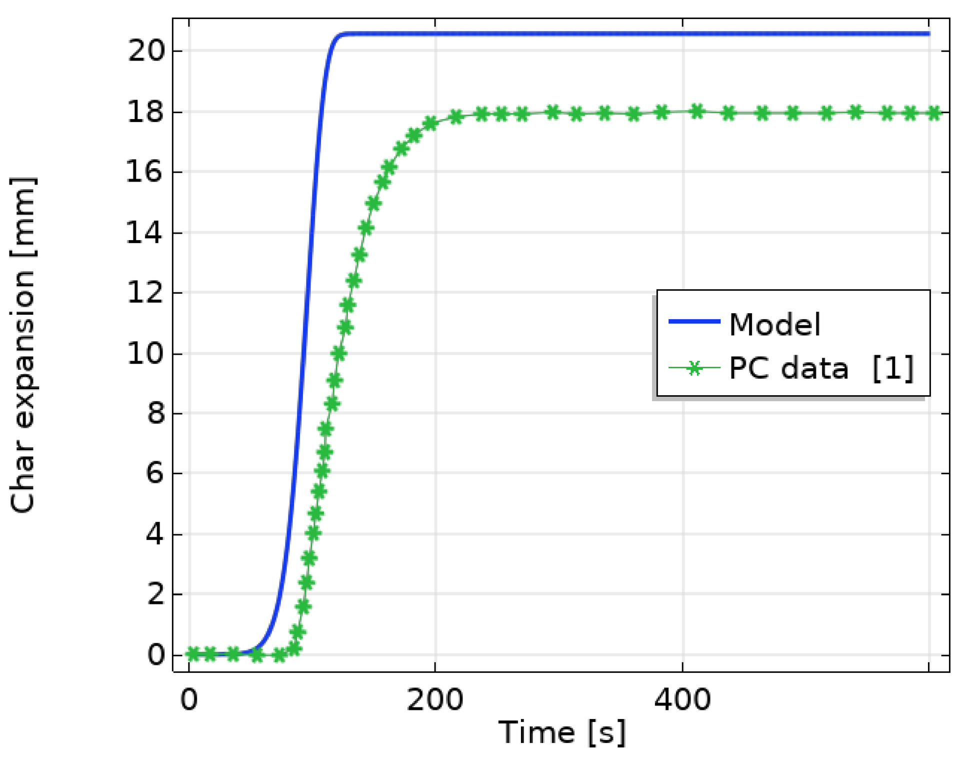
- Char cracking → non-constant coefficient of gases diffusion in the char (D_{char})



- Model input parameters for Polycarbonate (PC) from Statler et al. [1]

NUMERICAL SIMULATIONS





CONCLUSION

- Built engineering pyrolysis model (less experimental input parameters)
- Good prediction of PC combustion: predicted heat release rate, gas concentration, expansion, and temperature profiles
- Playing with model different parameters can help to improve material fire-retardancy (sensitivity analysis)

Reference:
[1] Statler Jr, D. L., & Gupta, R. K. (2008, October). A Finite Element Analysis on the Modeling of Heat Release Rate, as Assessed by a Cone Calorimeter, of Char Forming Polycarbonate. In Proceedings of the COMSOL Conference, Boston, MA, USA (pp. 9-11).

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