Imperial College London

One-dimensional model of pyrolysis and ignition of medium density fiberboard subjected to transient irradiation

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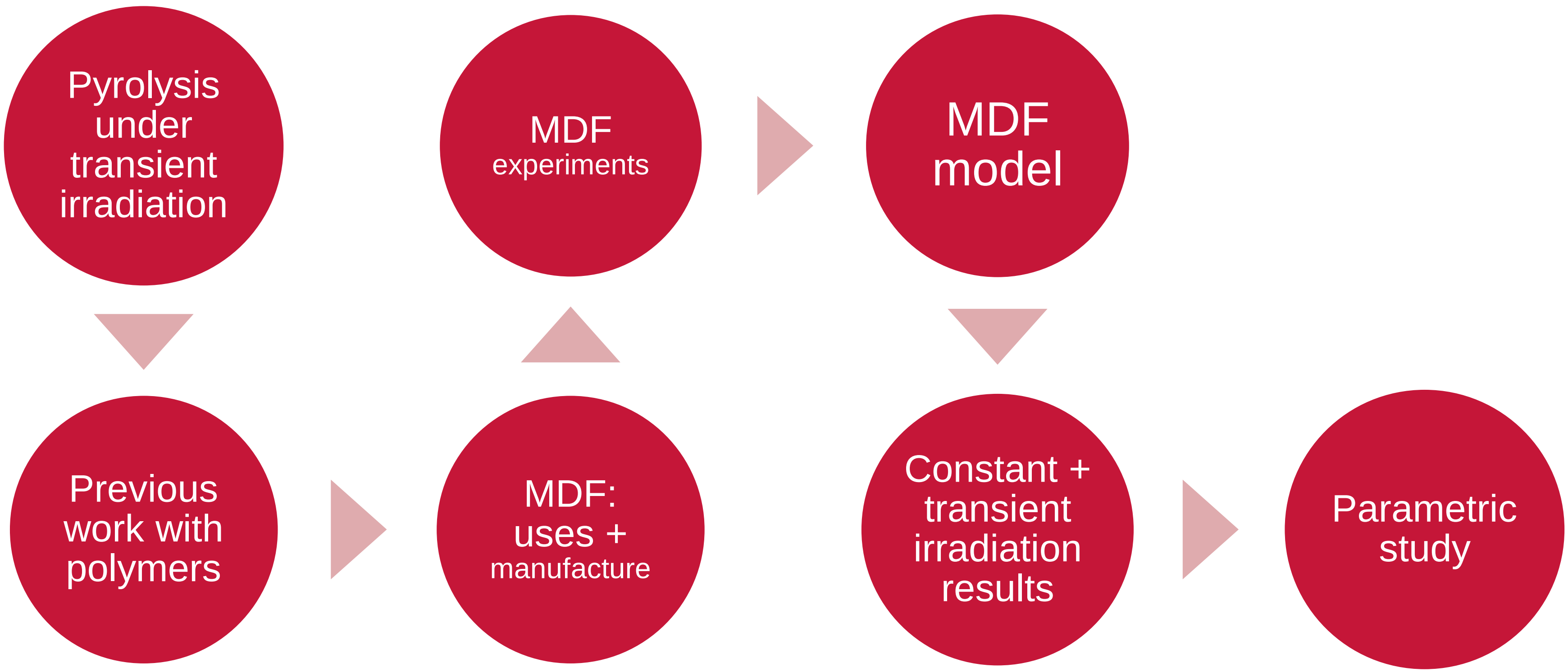
Torremolinos, ES

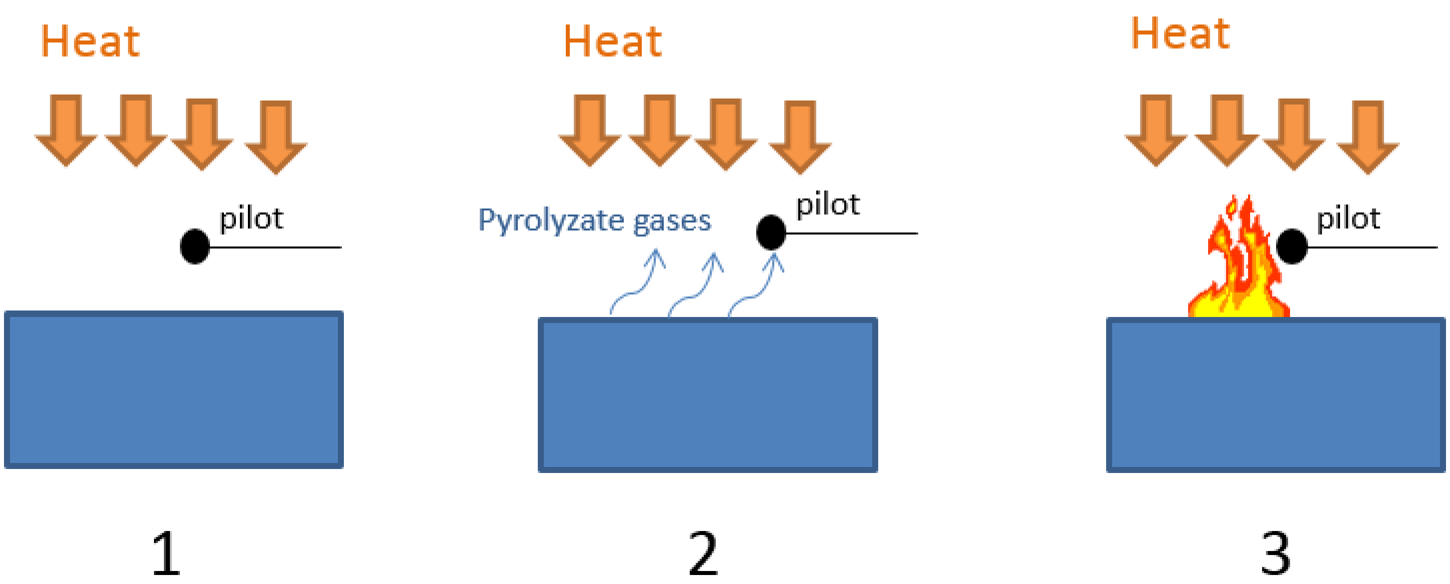
Presentation Outline



What is Pyrolysis?

Pyrolysis

= the process through which the solid undergoes a chemical decomposition and transforms into a gaseous fuel



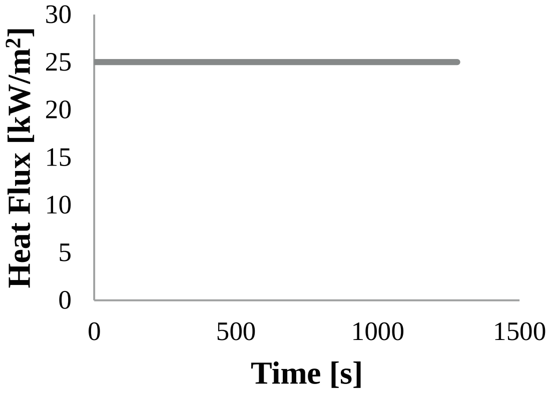
Importance of Pyrolysis

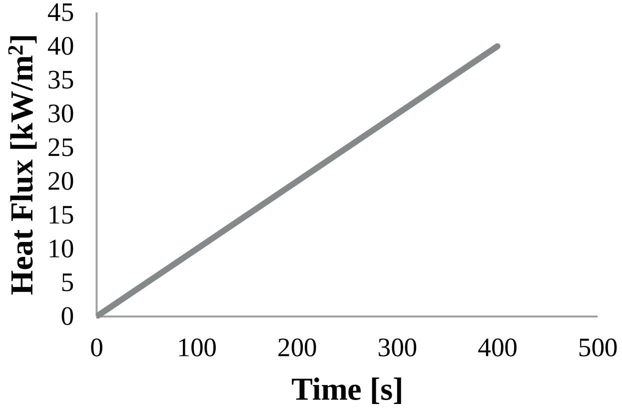
Ignition

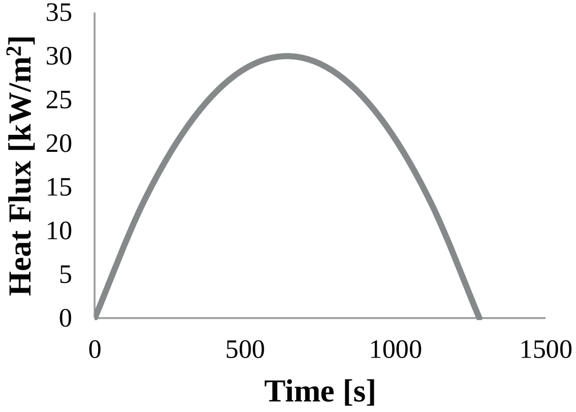
PYROLYSIS

Flame spread

Constant vs. transient



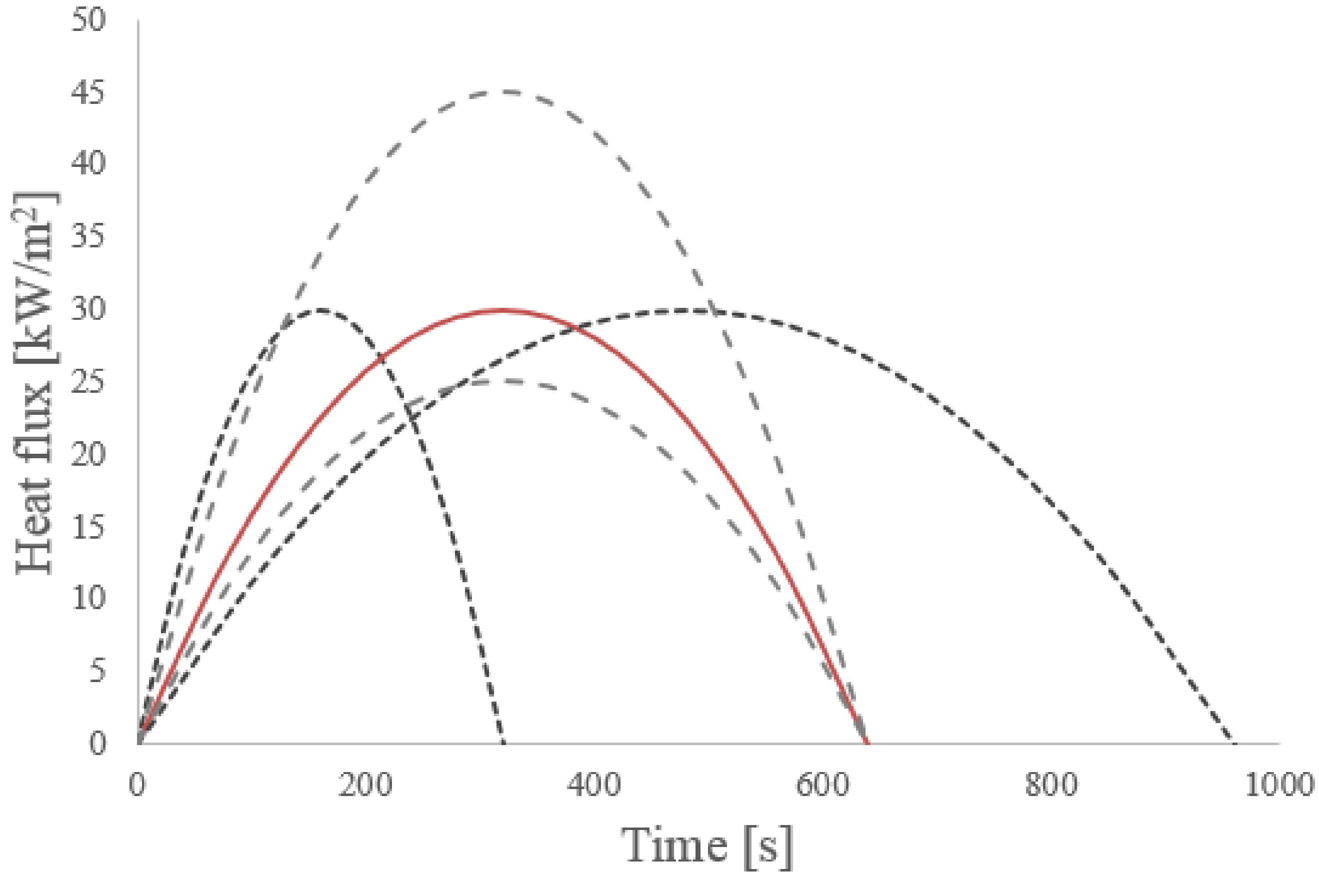




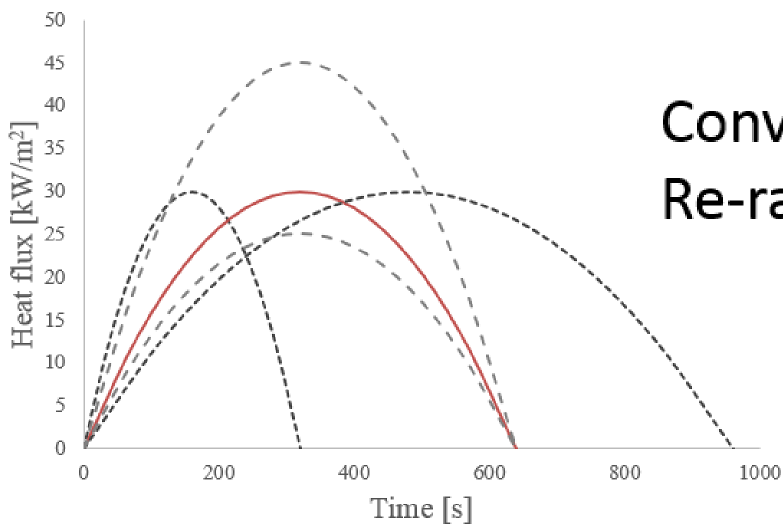
Transient scenario: state of the art

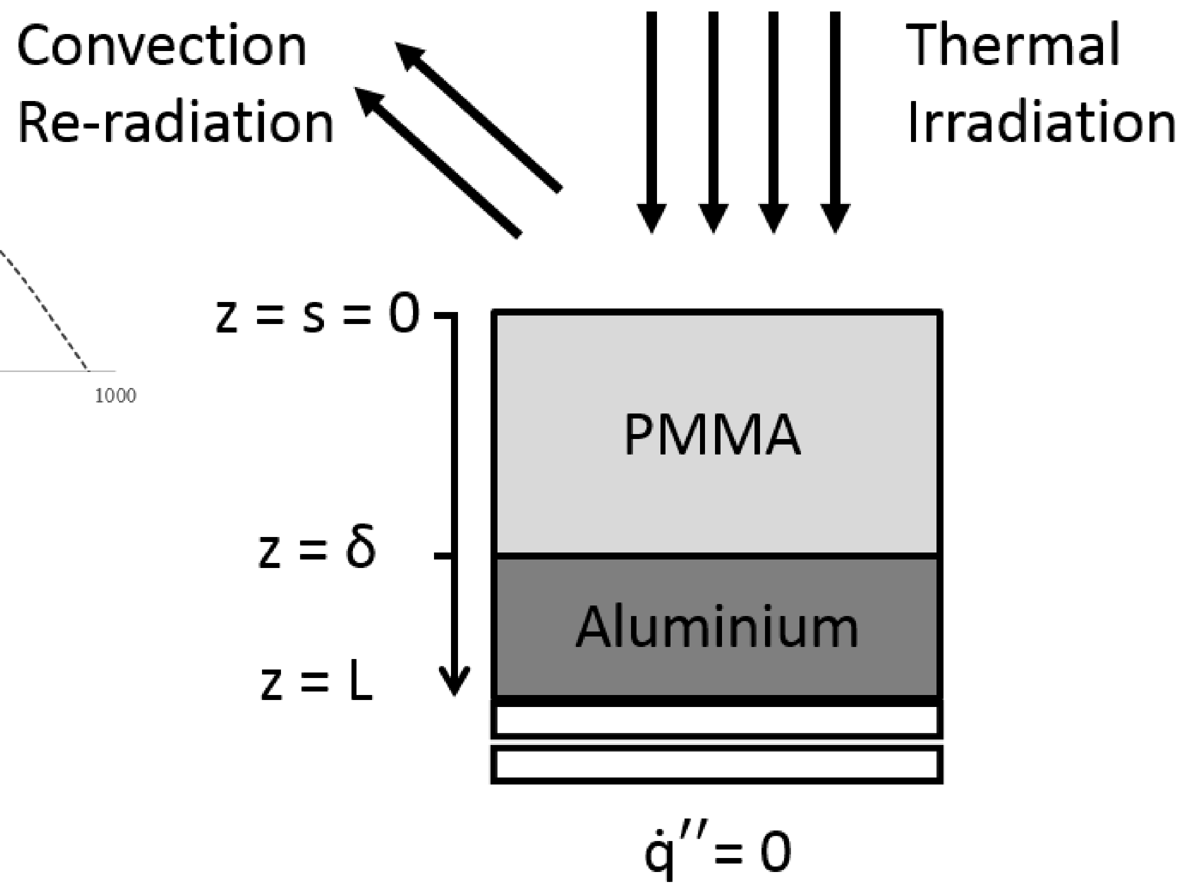
- Linear ramps:
  - Wood: Univ. Zaragoza (2000), USTC (2007), USTC (2016)
  - MDF: FM Global (2016)
  - Polymers: Univ. Edinburgh (2012)
- t^2 parabolic heat flux:
  - Wood: USTC (2016), Univ. Waterloo (2016)
- Parabolic pulses:
  - Forest fuels: Univ. Exeter (2015)
  - PMMA: Imperial College (2015)
  - MDF: Imperial College (2016)

Vermesi et al., Combust. Fl. 2016

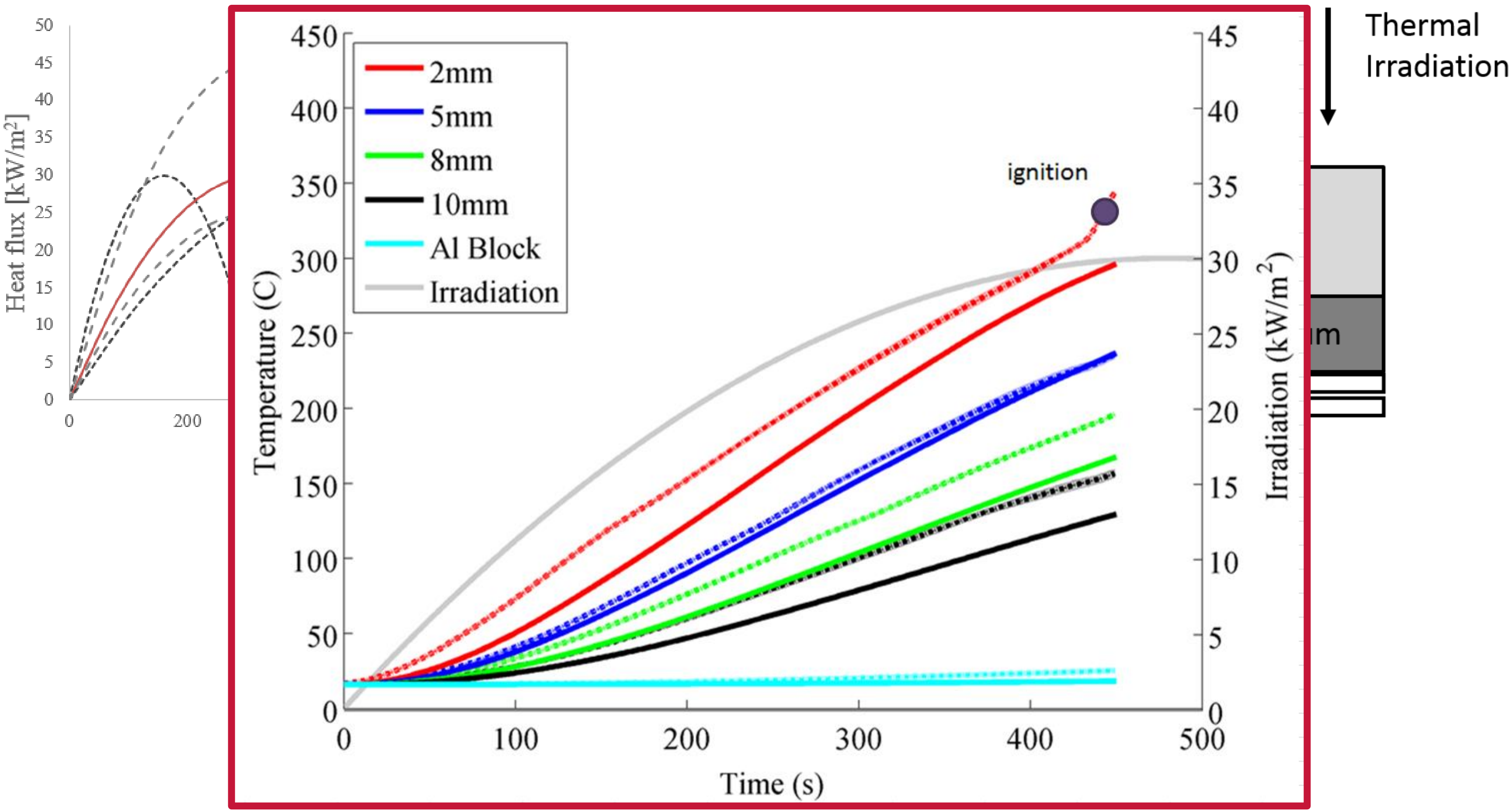


Vermesi et al., Combust. Fl. 2016





Vermesi et al., Combust. Fl. 2016

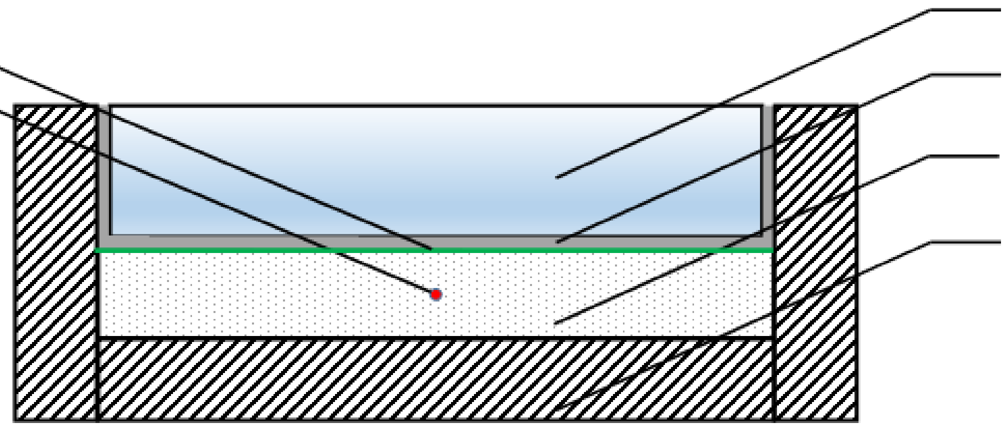


Medium density fiberboard

http://ifabstudio.com/wp-content/uploads/2014/03/MDF_DETALE.jpg

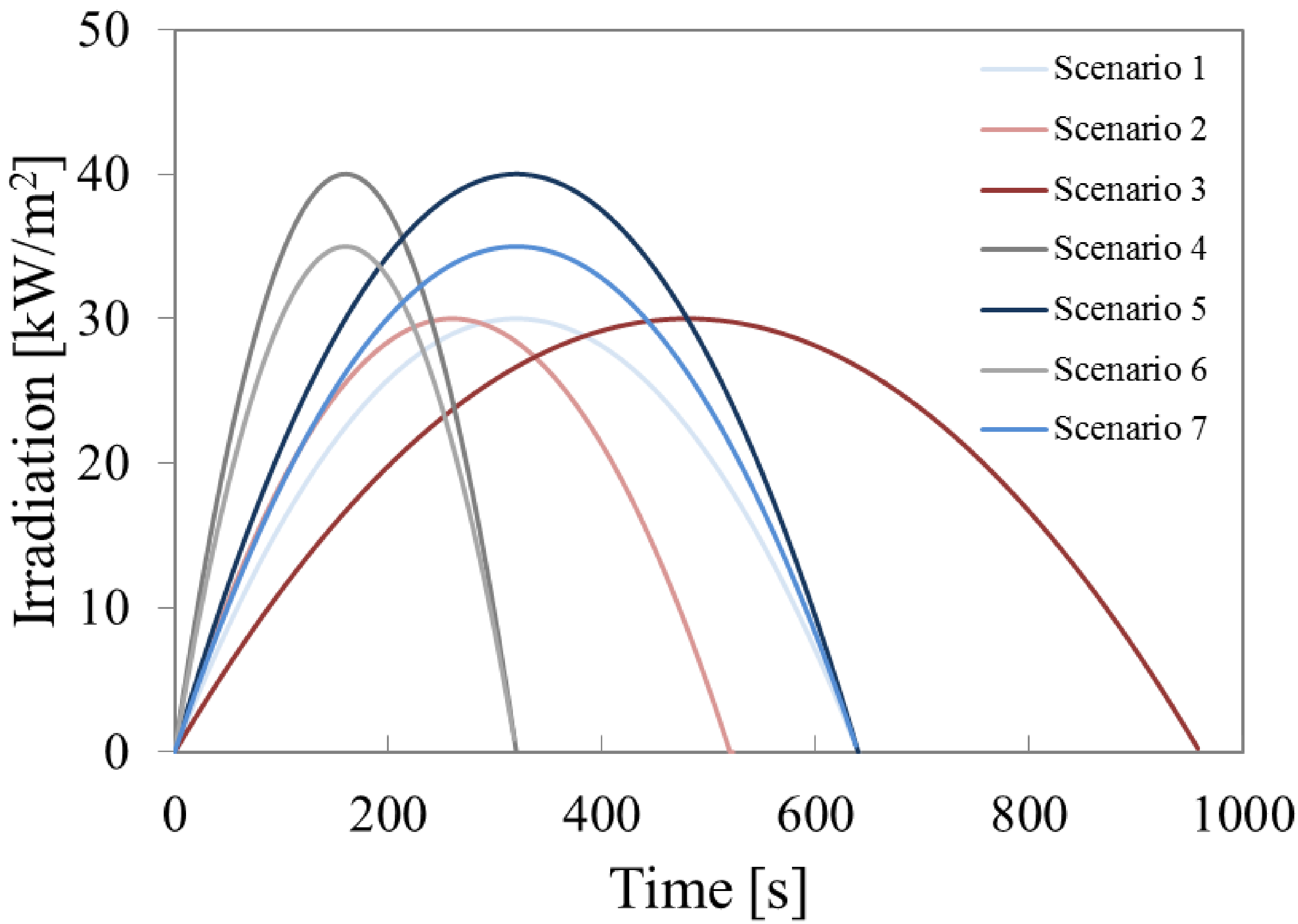
- Engineered wood product obtained from wood fibers glued together under heat and pressure
- Use in the indoor built environment: furniture, separating walls

MDF experiments



- FPA experiments using MDF samples with thickness of 30 mm
- Surface temperature measured with an IR pyrometer, mass loss measured with load cell

Irradiation Curves



MDF model

- 1D model in Gpyro (Lautenberger, Fire Saf. J., 2009)

- Boundary conditions:

$$-\bar{k}\frac{\partial T}{\partial z} = 0$$

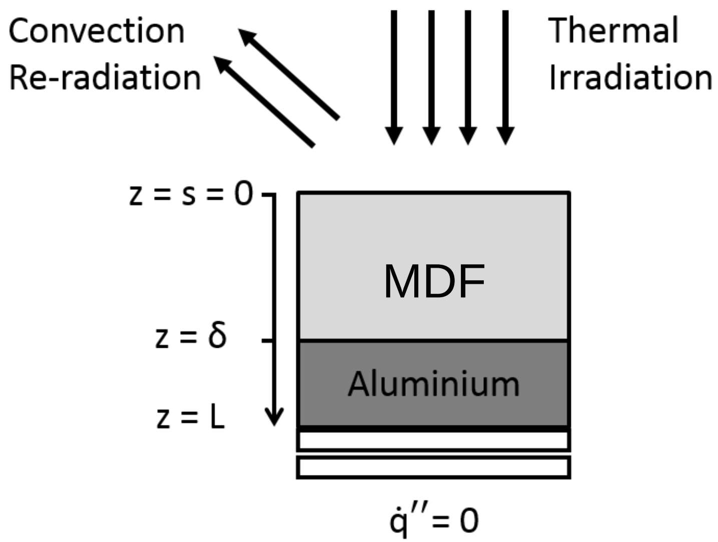
$$-\bar{k}\frac{\partial T}{\partial z} = \bar{\varepsilon}\dot{q}_e'' - h_c(T_s - T_0) - \bar{\varepsilon}\sigma(T^4 - T_0^4)$$

- Energy equation:

$$\frac{\partial(\bar{\rho}\bar{h})}{\partial t} = \frac{\partial}{\partial z}\left(\bar{k}\frac{\partial T}{\partial z}\right) + (-\dot{\omega}_{di}''')\Delta H_s - \frac{\partial \dot{q}_r''}{\partial z}$$

- Arrhenius equation for pyrolysis rate

$$\dot{\omega}_i = \frac{\partial m_i''}{\partial t} = m_{i0}'' A_i e^{-E_i/RT}\left(\frac{m_i''}{m_{i0}''}\right)^{n_i}$$



MDF model

$$wet\ wood \rightarrow dry\ wood + water\ vapour \qquad (drying)$$

$$hemicellulose \rightarrow char + pyrolyzate \qquad (hc)$$

$$cellulose \rightarrow char + pyrolyzate \qquad (cc)$$

$$lignin \rightarrow char + pyrolyzate \qquad (lc)$$

$$resin \rightarrow char + pyrolyzate \qquad (rc)$$

MDF model

$$\begin{aligned}
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&resin \rightarrow char + pyrolyzate && (rc)
\end{aligned}$$

Kinetic constants

Parameter	*drying*	*hc*	*cc*	*lc*	*rc*	*Units*	*Reference*
Pre-exponential factor log A	8.12	12.9	13.6	16.3	13.6	$\log(s^{-1})$	Li, Huang et al., 2014
Activation energy E	67.8	165	189	238	149	kJ/mol	Li, Huang et al., 2014
Heat of pyrolysis ΔH	0	256	256	256	256	kJ/kg	Li et al., 2015
Reaction order n	2.37	2.4	0.84	10.4	4.7	-	Li, Huang et al., 2014

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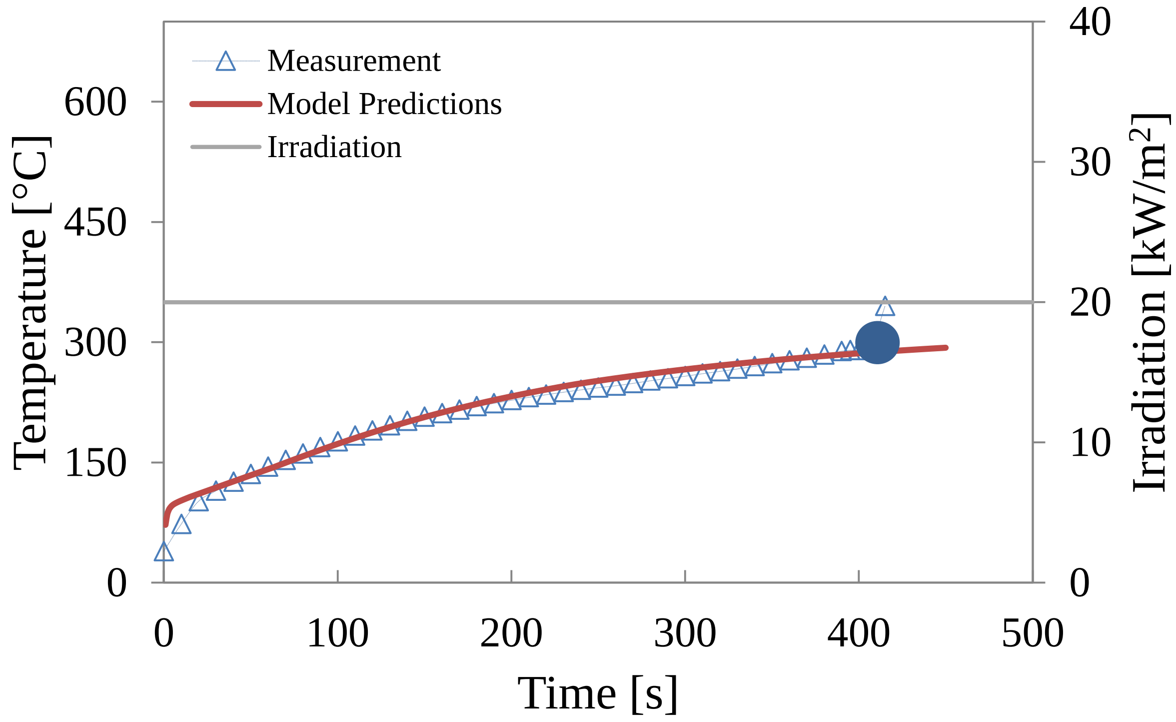
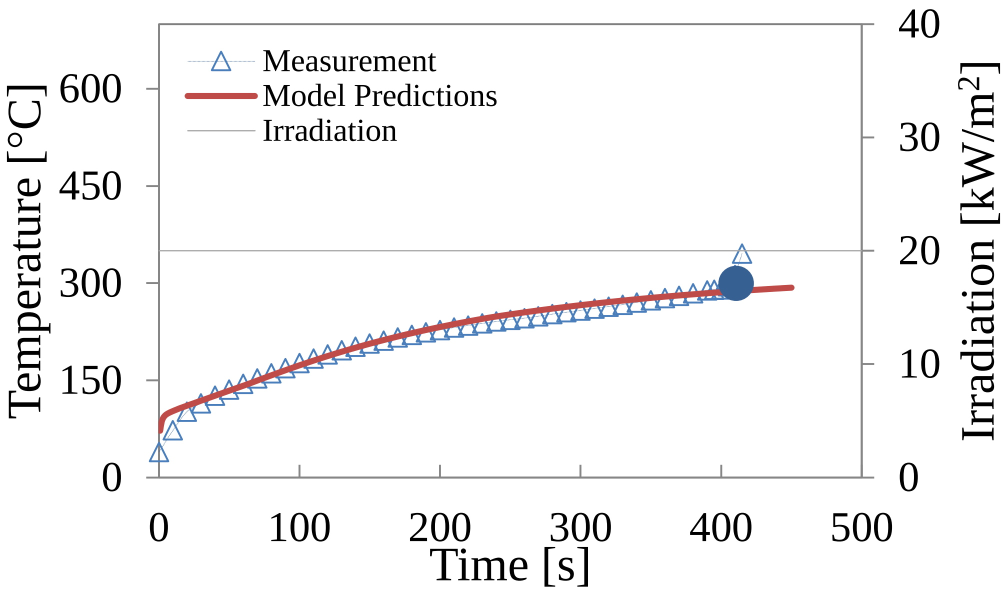
Temperature dependent properties

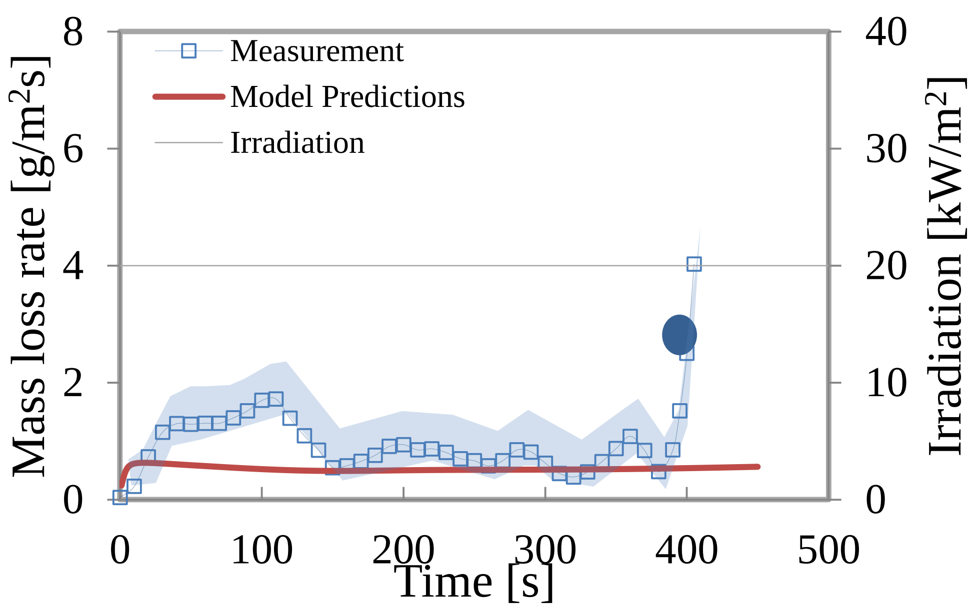
Property	*Value*	*Exponent Value*	*Units*	*Reference*
Thermal conductivity k	0.12	0.49	W/mK	Li et al., 2013
Density ρ	605	-	kg/m^3	measurement
Specific heat capacity c_p	1489	0.85	J/kgK	Li et al., 2013
Surface emissivity of MDF ϵ	0.8	-		Boulet et al., 2012
Thermal conductivity of char k_{char}	0.09	3.90	W/mK	Li et al., 2013
Density of char ρ_{char}	330	-	kg/m^3	Li et al., 2013
Specific heat capacity of char $c_{p,char}$	600	1.15	J/kgK	Li et al., 2013

MDF results: constant irradiation



MDF results: constant irradiation





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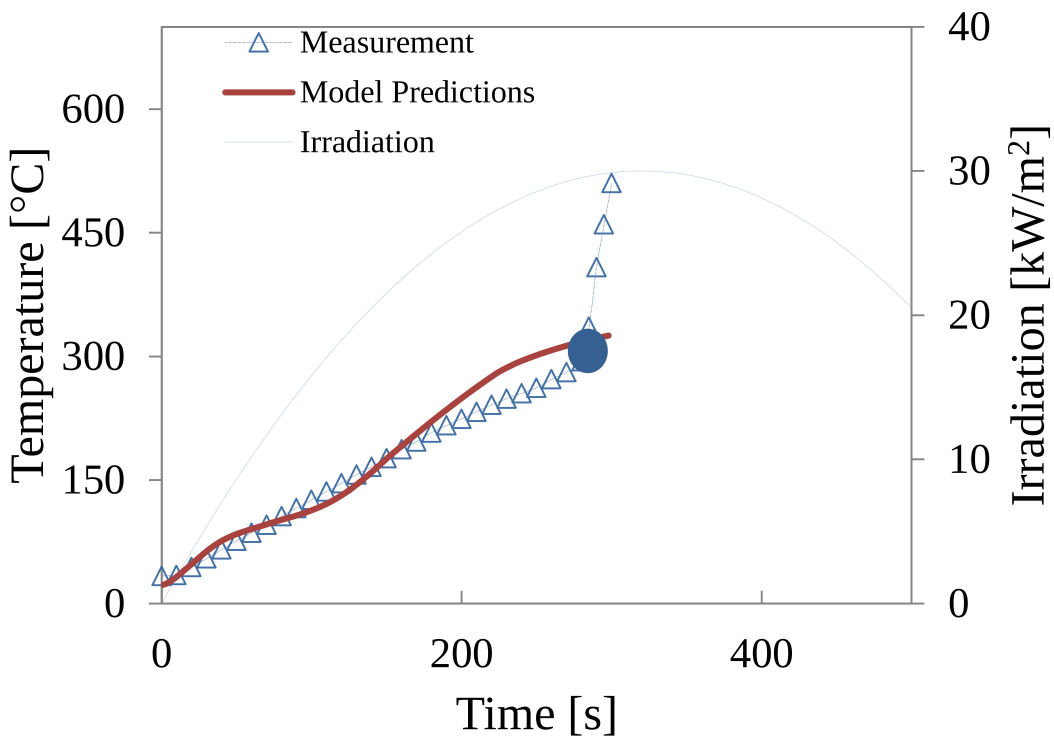
MDF results: transient irradiation



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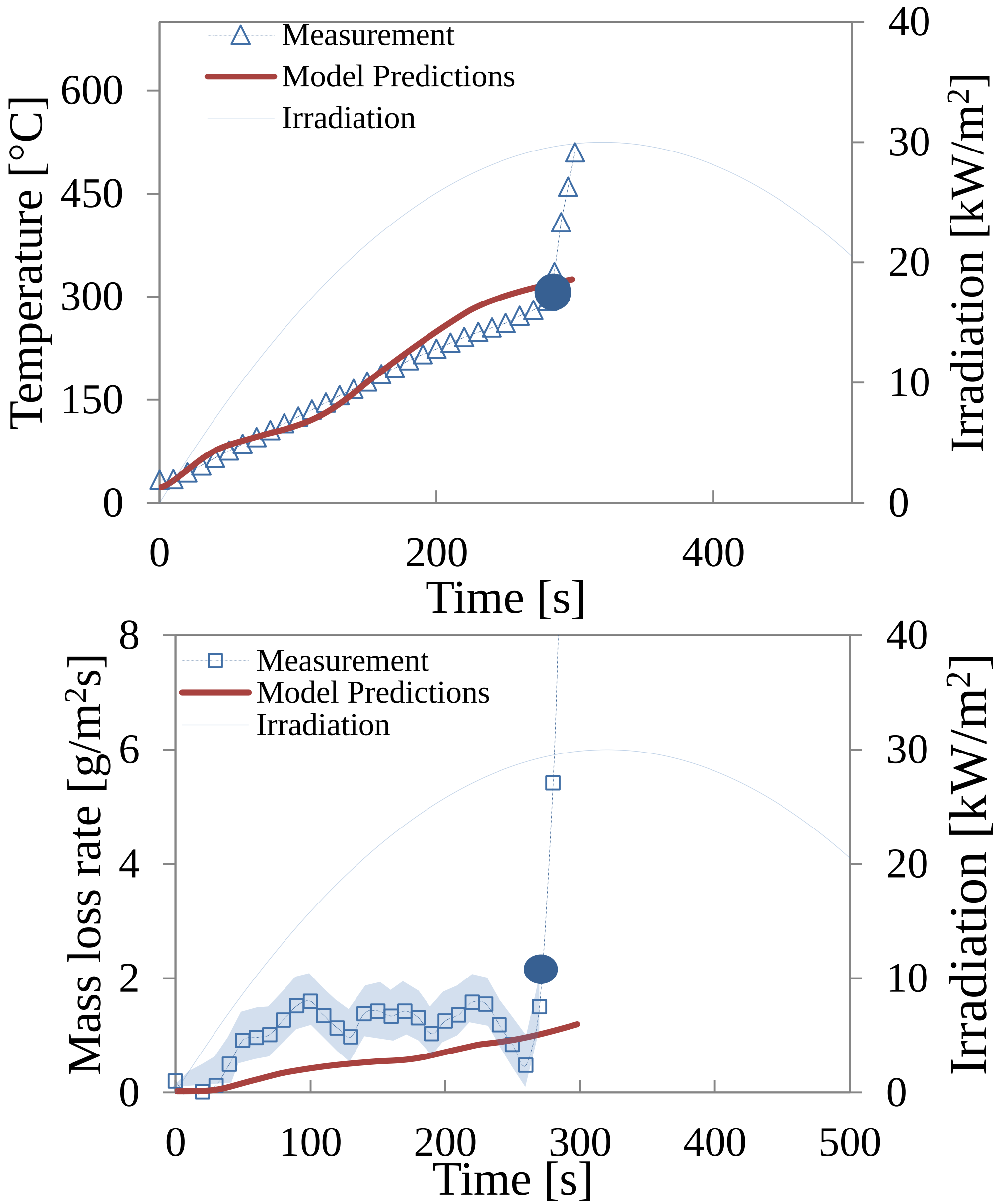
MDF results: transient irradiation

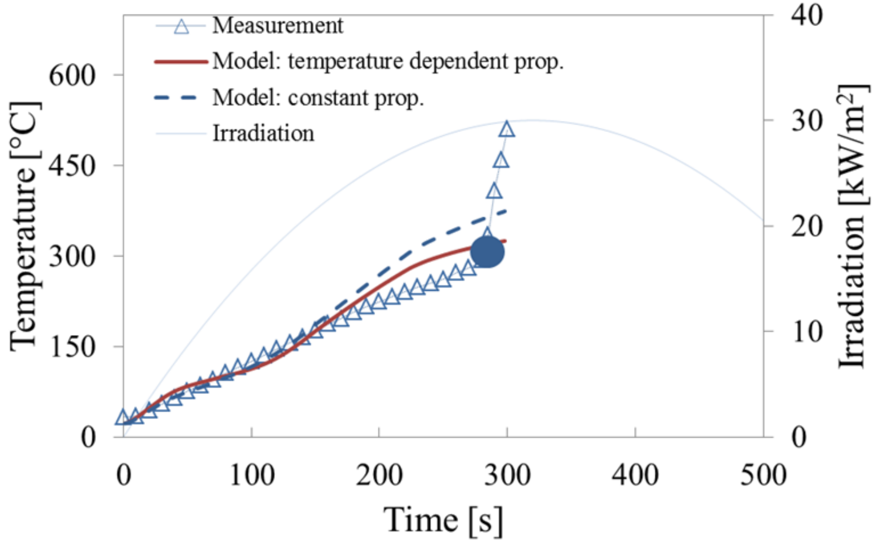


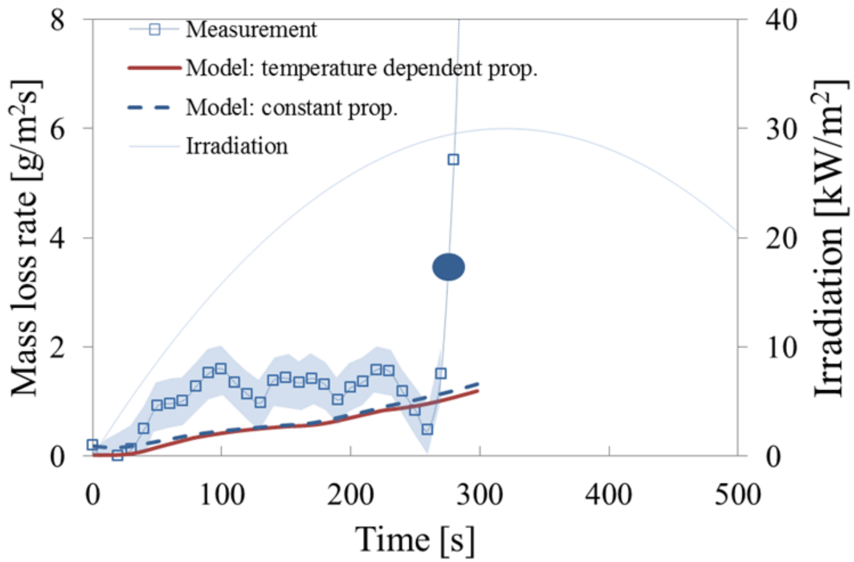
Parametric study

- Thermal properties that remain constant with temperature vs. temperature-dependent properties

- Influence of the drying step in the kinetics scheme

Constant vs. temperature dependent properties





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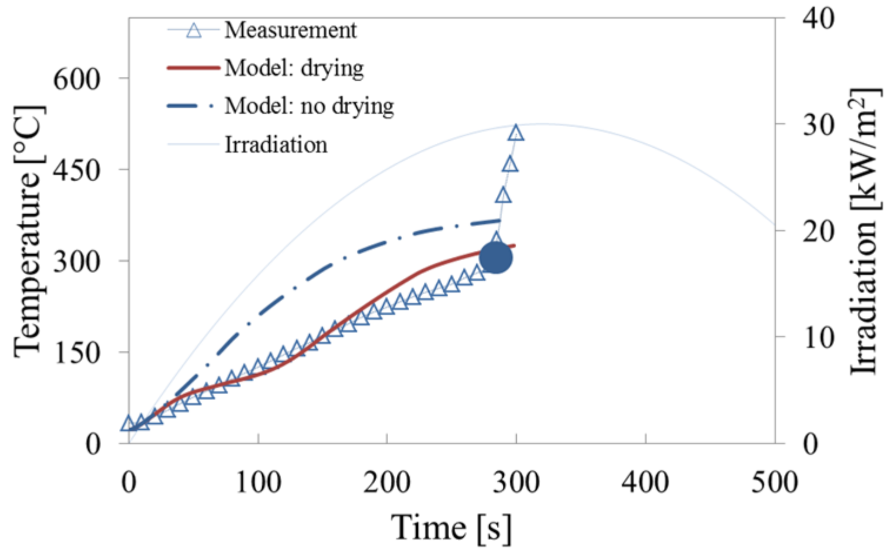
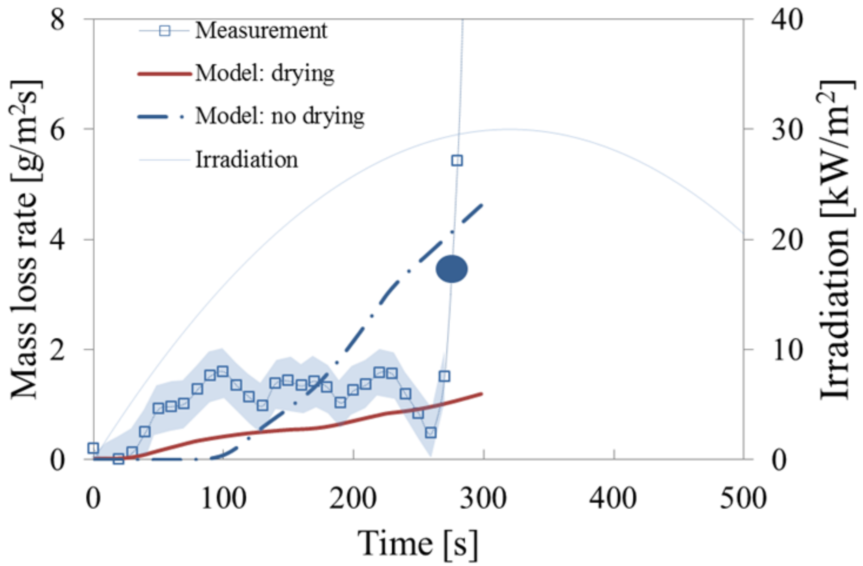
Influence of drying





Conclusions

- MDF subjected to transient irradiation ignited in all scenarios
- MDF experiments modelled in 1D in Gpyro (no optimization, only values from literature and measurements)
- Surface temperatures are well predicted for both materials
- Mass loss rate is predicted qualitatively
- Drying is an essential step in modelling MDF
- Using temperature dependent properties improves the results slightly, but is not as influential as drying

Thank you for your attention!

Questions?

Acknowledgements:

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