TIME-TEMPERATURE HISTORY OF FUEL PARTICLES DURING CO-COMBUSTION OF HIGH-VOLATILE SOLID FUELS WITH COAL

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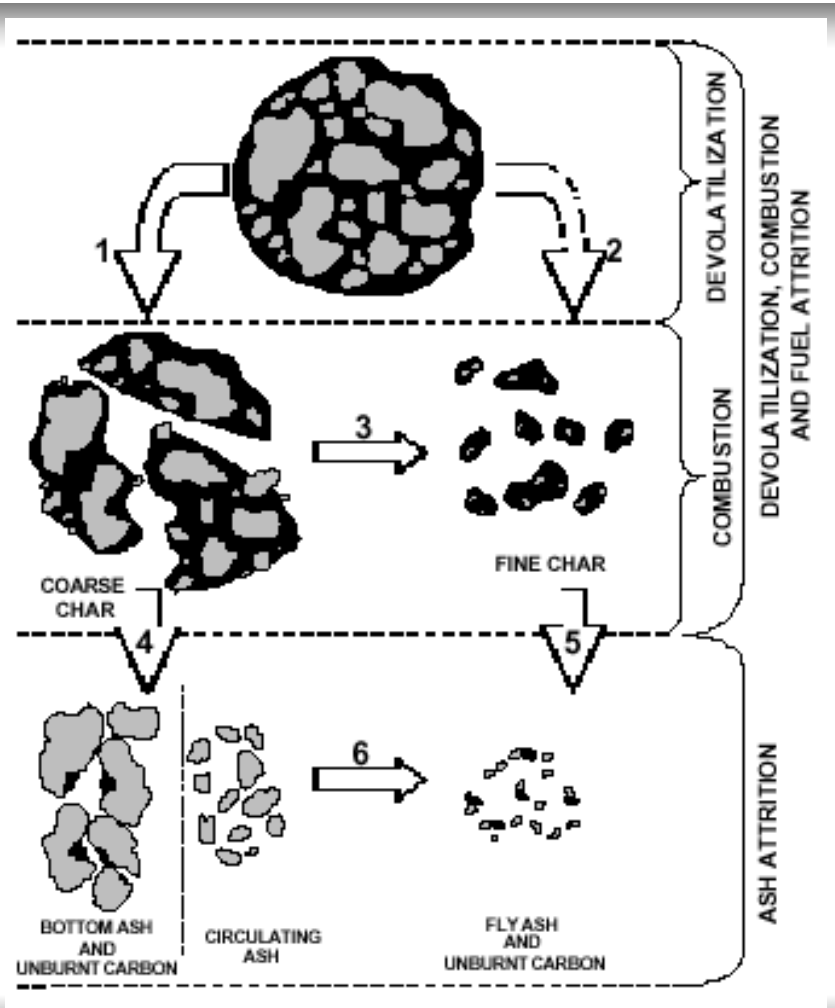
QUESTIONS TO BE ANSWERED

- What is attrition?
- How can attrition be assessed?
- How does attrition affect fuel particles time-temperature history (and associated fate of fixed carbon and ash)?

FUEL AND ASH
ATTRITION IN FLUIDIZED BEDS

Chirone, Massimilla and Salatino,
Prog. Energy Combust. Sci.
17, 297 (1991)

Cammarota, Chirone, Marzocchella and
Salatino, CFB7, 2002



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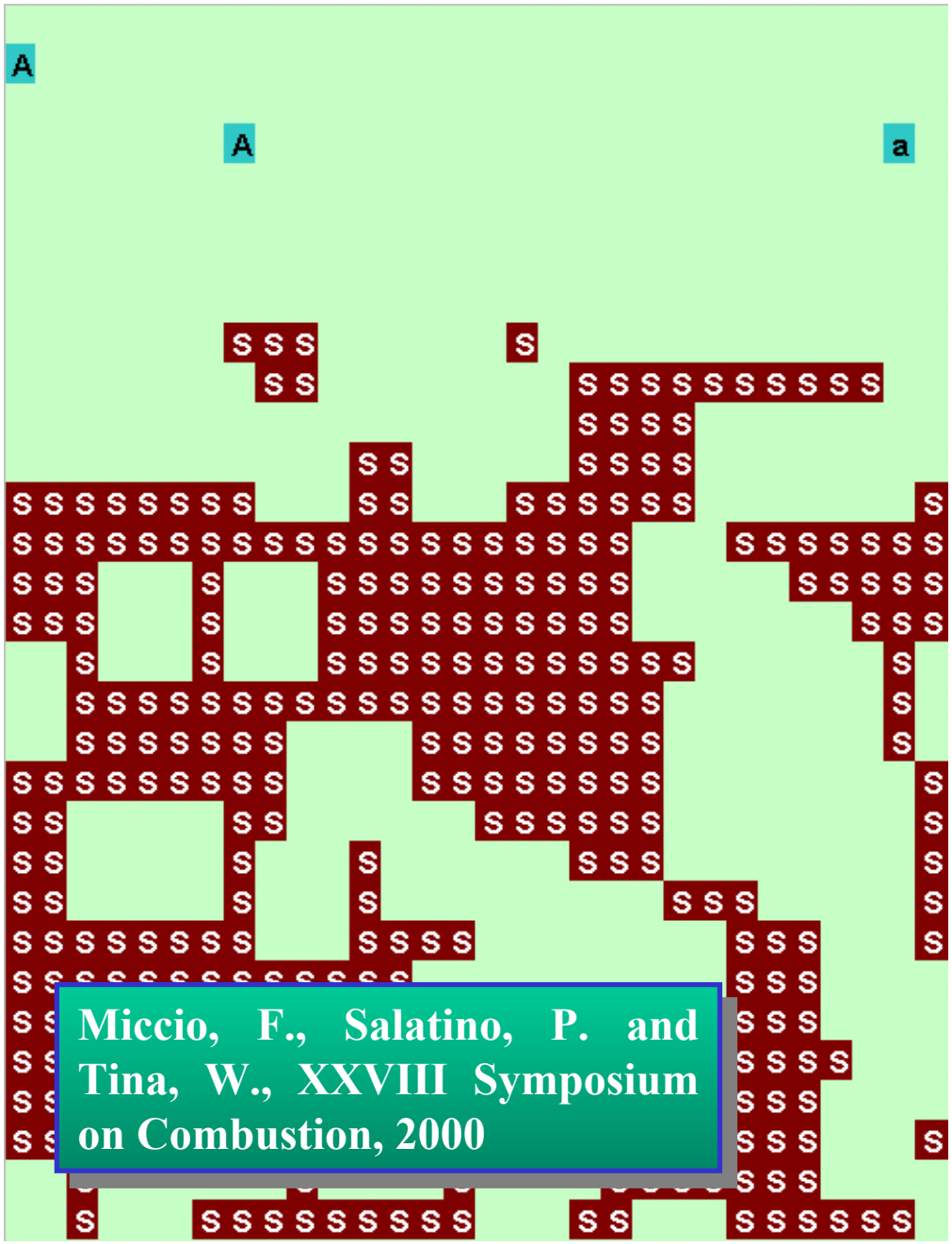
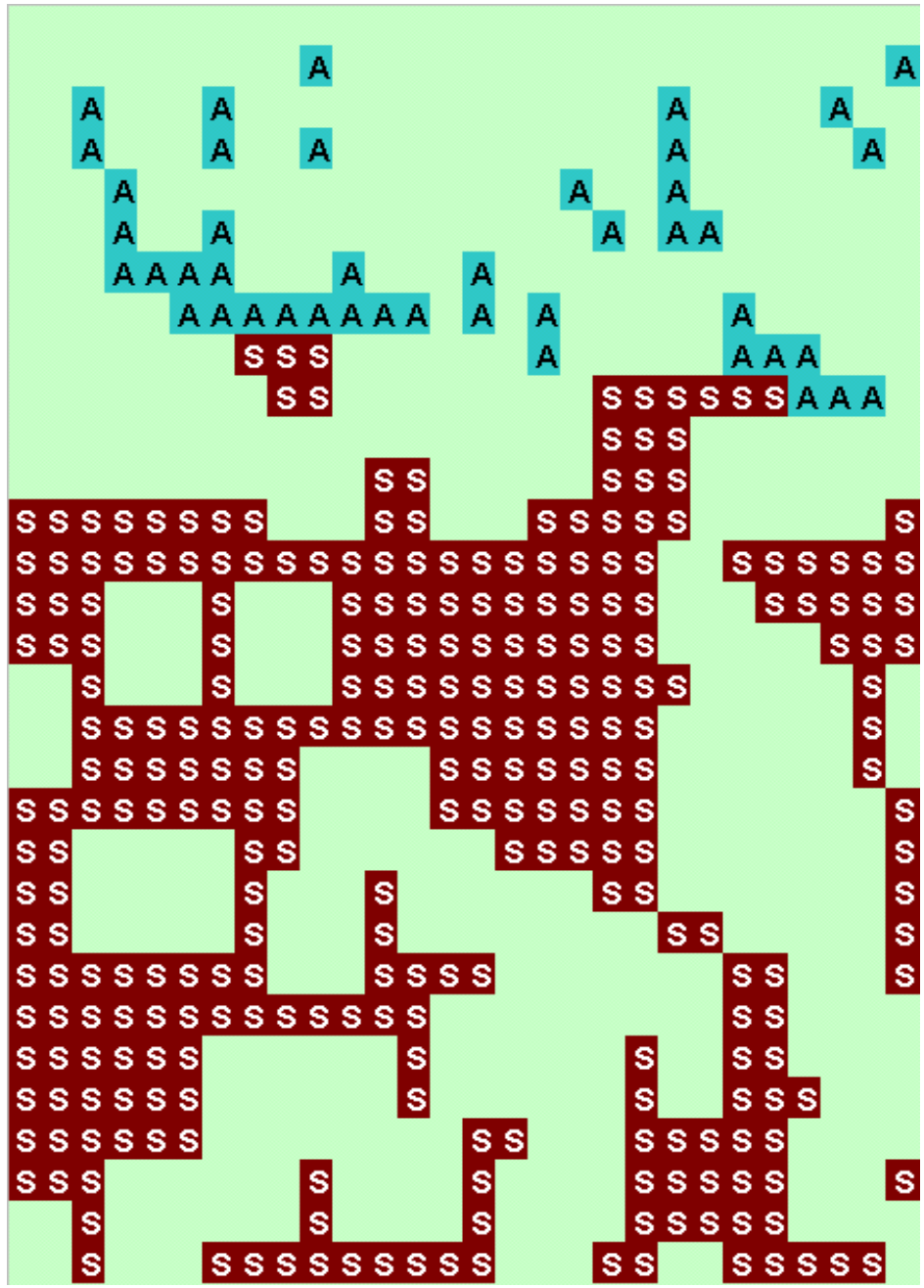
FUEL ATTRITION MECHANISMS

- Primary fragmentation:
  - breakage of particles induced by internal mechanical stresses associated with thermal shock and/or release of volatile matter;
  - Influenced by particle size, heating rate, peak temperature, fuel texture (e.g. porosity), volatile matter content, …..

FUEL ATTRITION MECHANISMS

- Fragmentation by loss of particle connectivity:
  - Fragmentation of particles associated with enlargement and overlapping of pores and cavities followed by loss of particle connectivity (percolative fragmentation);
  - Influenced by particle texture and gasification regime.



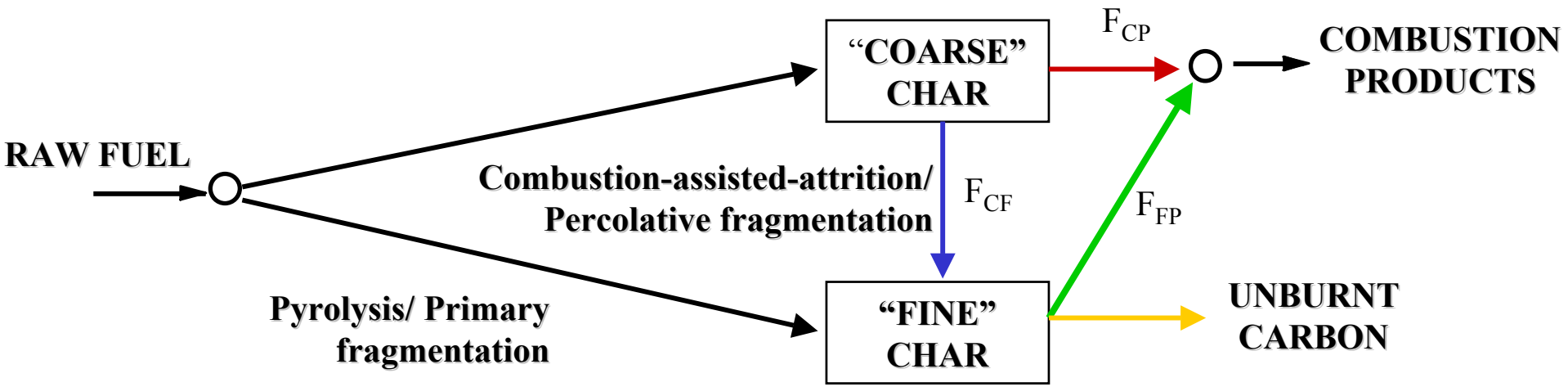


M=1.0 conv. degree **0.3** M=0.01

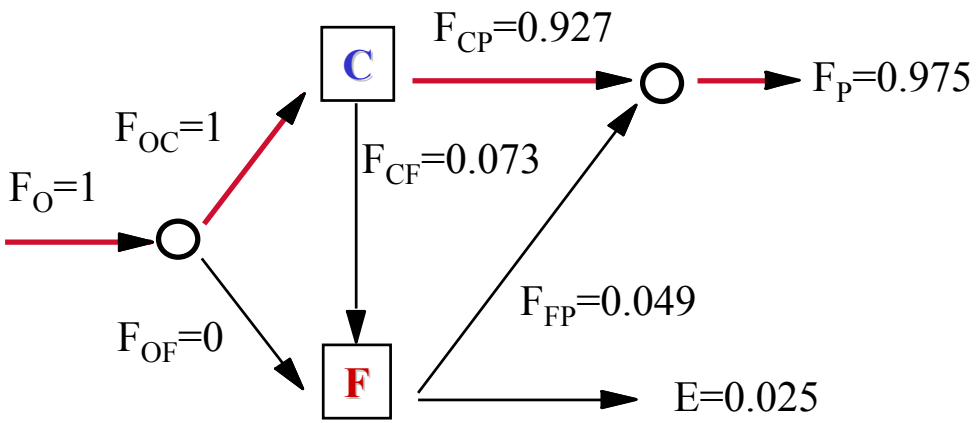
FUEL ATTRITION MECHANISMS

- Fragmentation by the action of external forces:
  - Surface wear (abrasive attrition);
  - Impact loading (e.g., in jets);
  - Enhanced by the progress of combustion (Combustion-assisted-attrition).

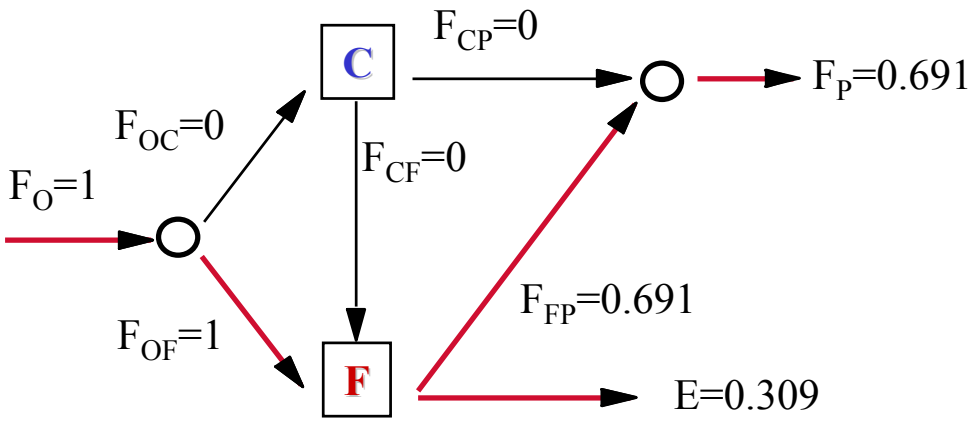
FUEL COMBUSTION/ATTRITION PATTERN



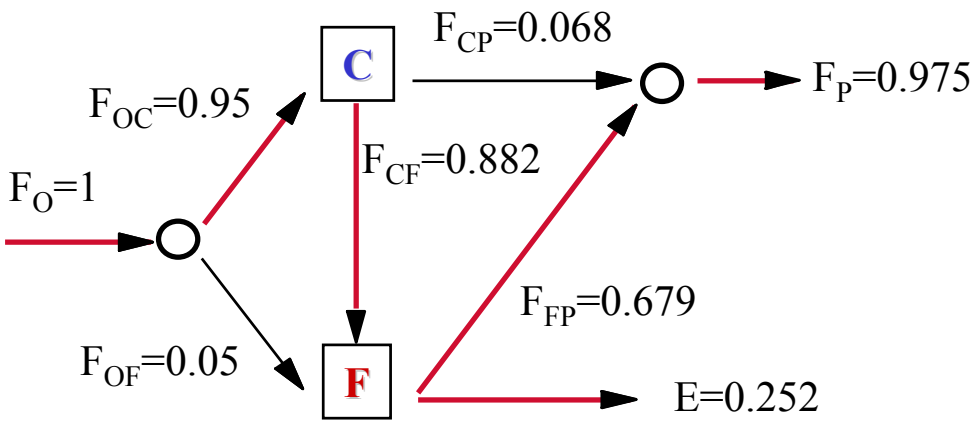
COMBUSTION/ATTRITION PATTERNS: Bituminous Coal



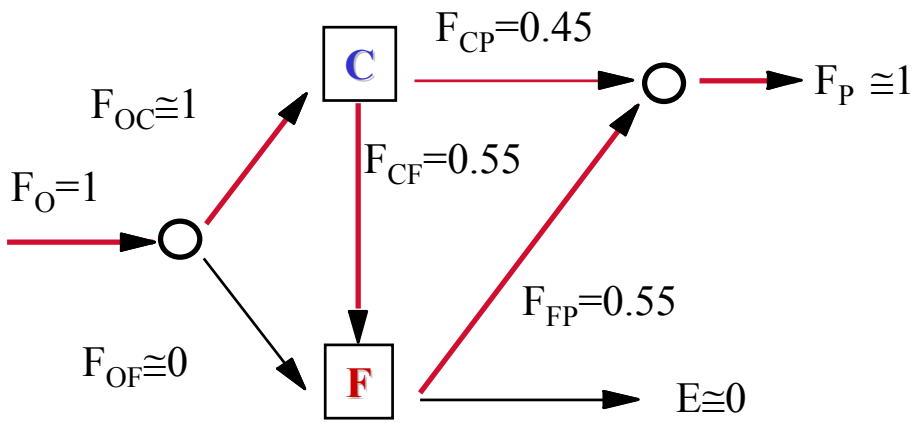
COMBUSTION/ATTRITION PATTERNS: Tyre-derived Fuel



COMBUSTION/ATTRITION PATTERNS: Refuse-derived Fuel

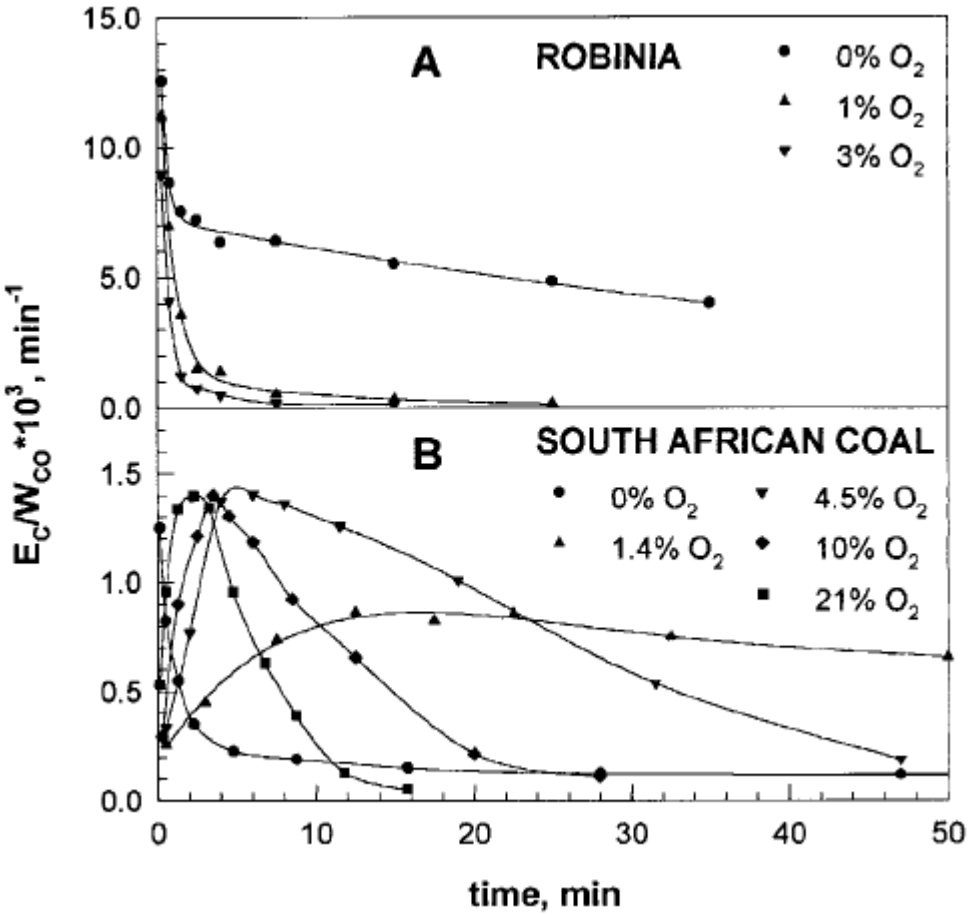


COMBUSTION/ATTRITION PATTERNS: Biomass (Robinia Pseudoacacia)



ASSESSMENT OF ATTRITION

- Low-reactivity carbons: afterburning of attrited fines is limited → the extent of attrition can be directly assessed by looking at unburned carbon at the exhaust;
- High-reactivity carbons: burnout of attrited carbon fines is extensive over their residence time in the combustor → attrition cannot be directly assessed from unburned carbon at the exhaust. Other methods have to be envisaged.



U=0.8m/s
T=850°C

Robinia: d_{fuel}=10mm
Coal: d_{fuel}=5.5mm

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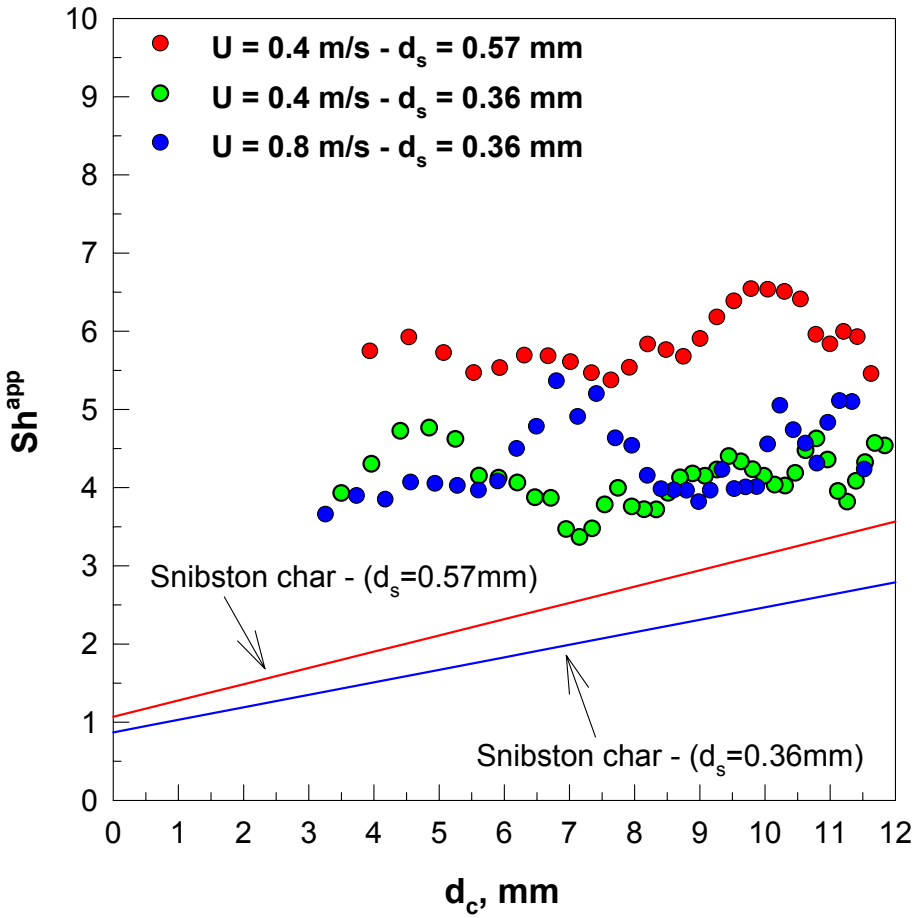
ASSESSMENT VIA ENHANCEMENT OF COMBUSTION RATE

Salatino, Scala, Chirone, Proc. Comb. Inst. 27, 3103 (1998)

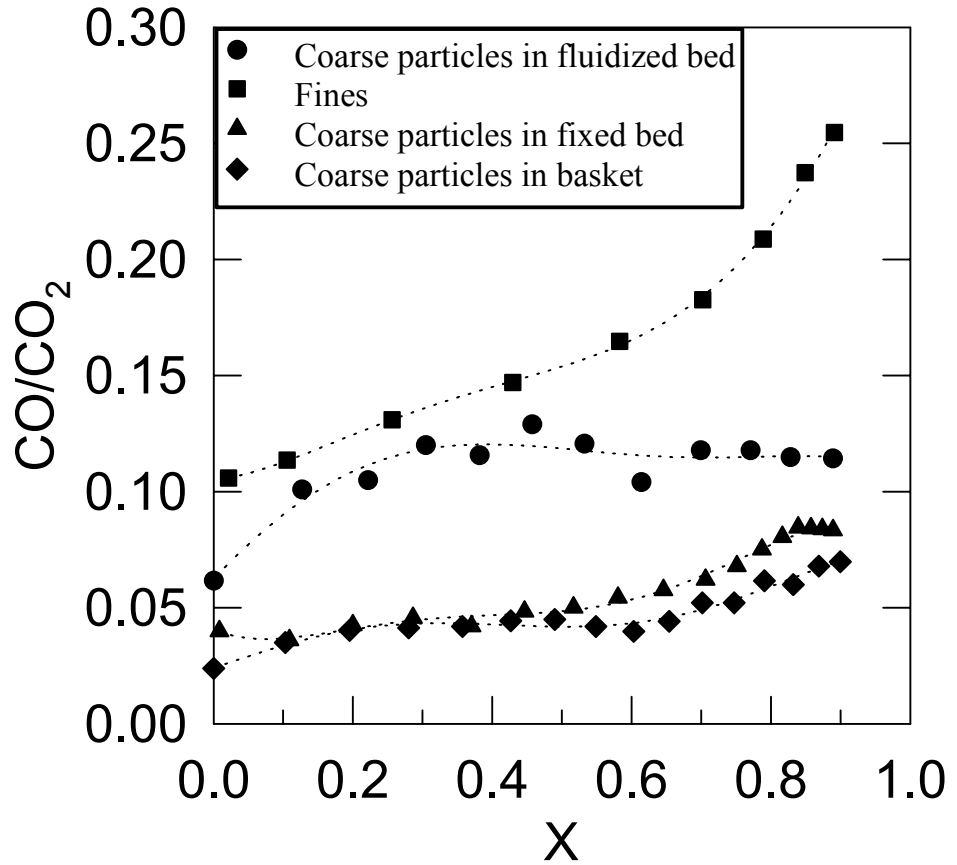
$$(1+\alpha)C_{\text{coarse char}} + O_2 \rightarrow CO_2 + \alpha C_{\text{generated fines}}$$

$$\alpha C_{\text{generated fines}} + \alpha O_2 \rightarrow \alpha CO_2$$



ASSESSMENT VIA ANALYSIS OF THE CO/CO_2 RATIO AS PRIMARY COMBUSTION PRODUCTS

Chirone, Greco, Salatino, Scala, Proc of 14th Int. Conf.. on FBC, Vancouver (1997)



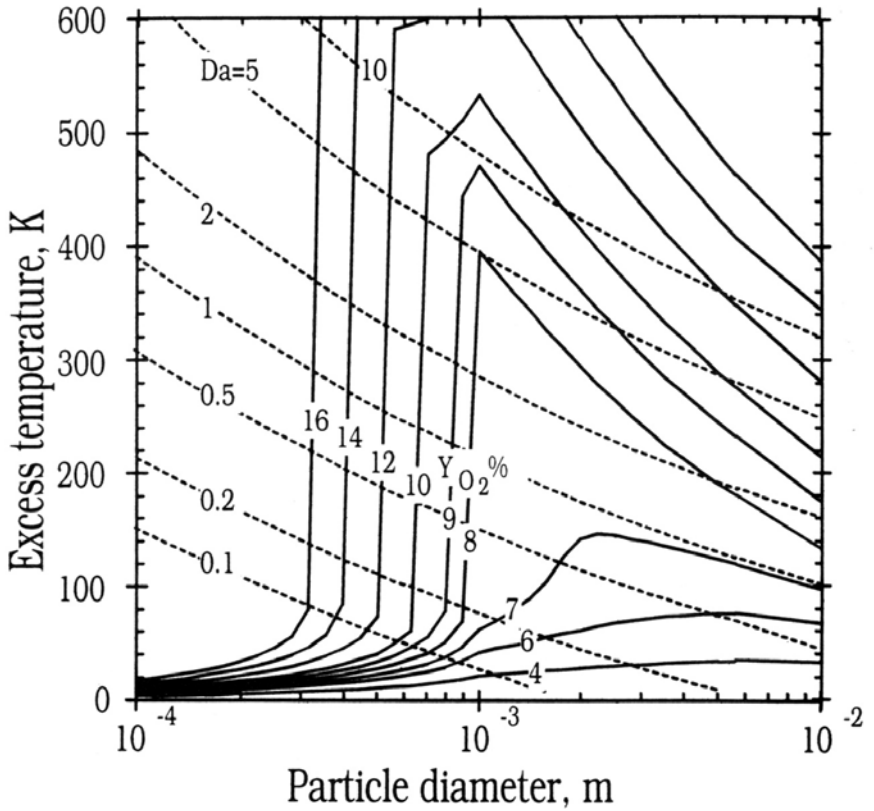
INFLUENCE OF COMMINUTION PHENOMENA ON THE FATE OF FUEL PARTICLES

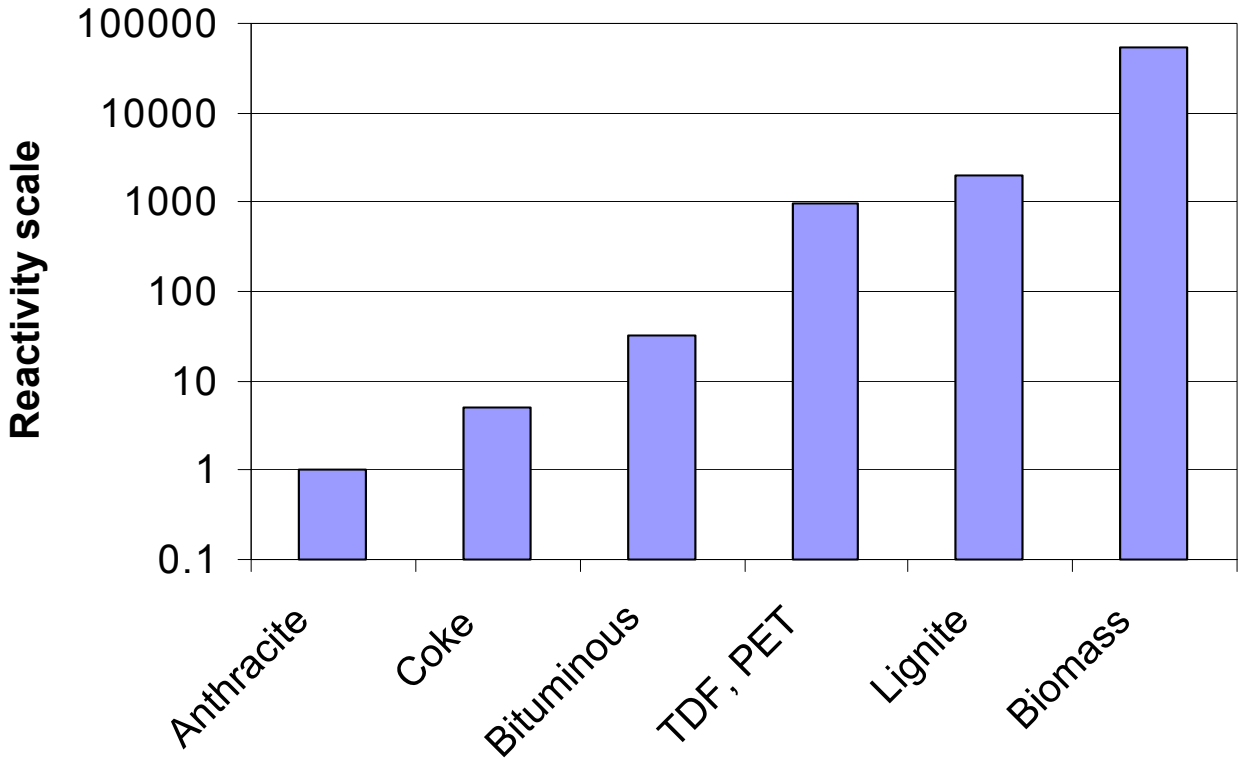
- Comminution affects average particle size, and in turn:
  - Residence time of the fuel particles in the reactor;
  - Heat and mass transfer;
  - Intraparticle diffusion and heat transfer;
  - Time-temperature history and fuel burnoff.

TIME-TEMPERATURE HISTORY OF CHAR PARTICLES

Palchonok et al., Proc of 14th Int. Conf.. on FBC, Vancouver (1997)

$$Da = \frac{k_c}{k_g}$$





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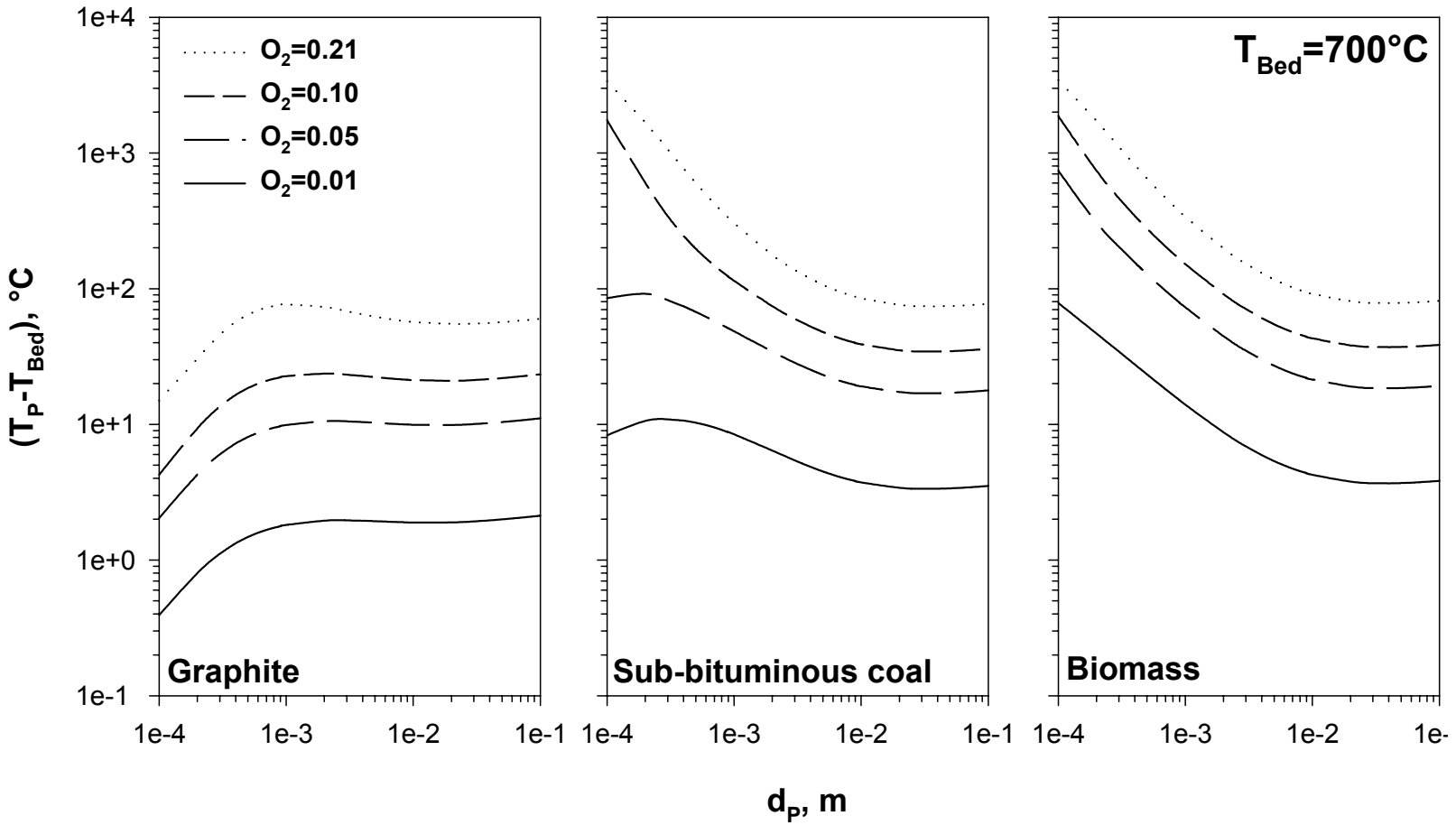

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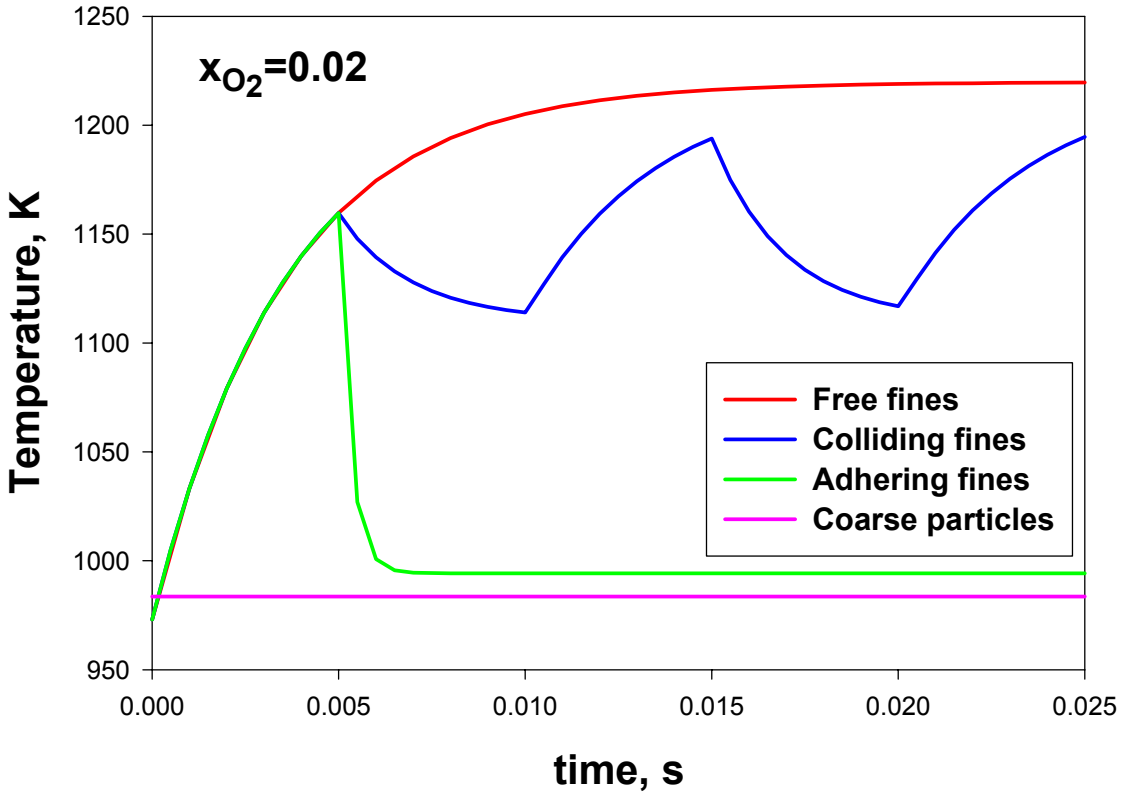
TEMPERATURE HISTORY OF CHAR PARTICLES

Robinia Pseudoacacia

Scala, Salatino and Chirone, Proc. Comb. Inst., 28 (2000)



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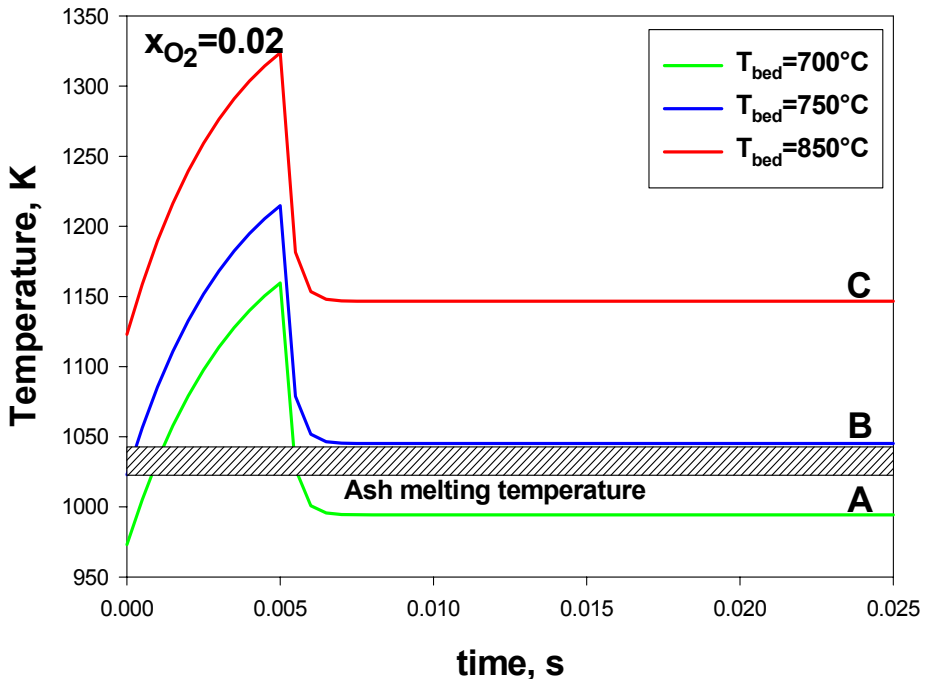

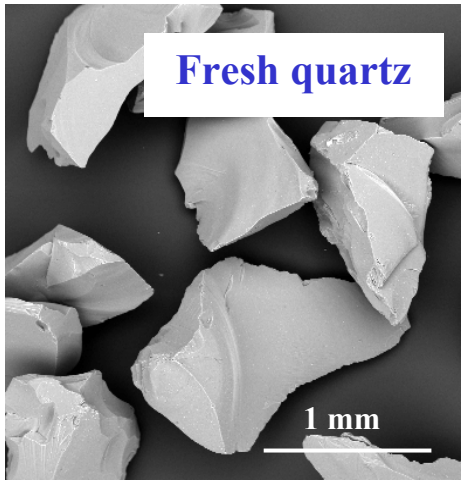

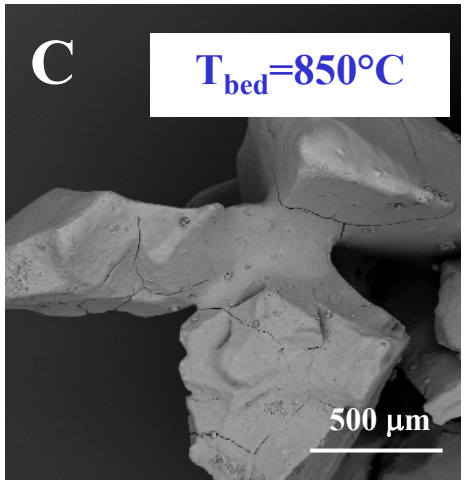

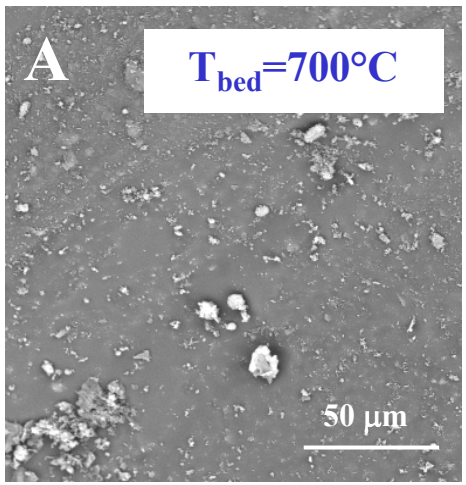

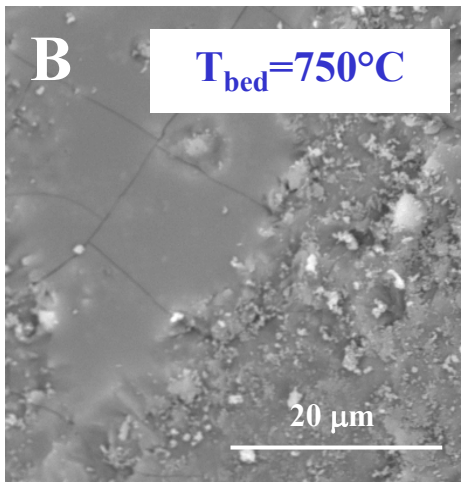

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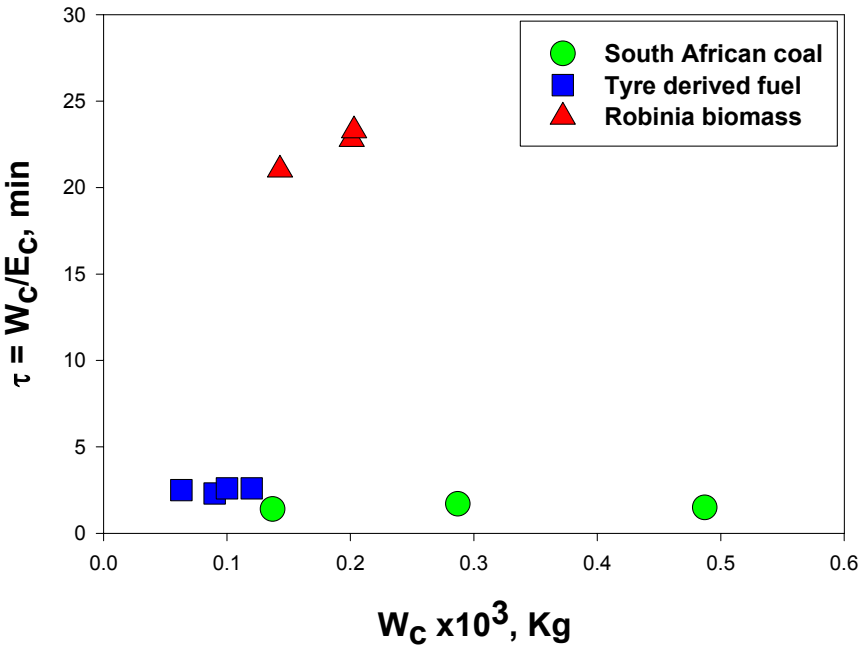
Average residence time of fines in FBC



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