Conversion of pyrolysis oil droplets under Entrained Flow Gasifier conditions

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Objectives

Model based description for conversion of pyrolysis oil under elevated temperature and pressure:

- Numerical approach for depicting the single steps of conversion
- Input data for numerical simulation of technical EFG

Challenges

Experimental validation of evaporation model and reliable characterization of feedstock:

- Complex mixture of multiphase composition
- Multistep conversion and formation of solid residue
- Adaption of measuring techniques for droplet evaporation

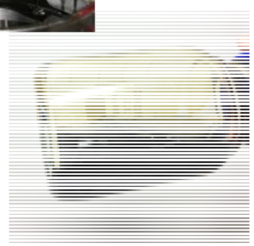
Fuel Characterization

Pyrolysis oil

Chemical composition:
- Large variety of organic liquids
- High amount of oxygenated compounds

Physical Properties:
- High-viscous non-Newtonian fluid
- Wide range of boiling points
- High amount of non-vaporizing components

Challenges:
- No complete dissolution of chemical components
- No fractional distillation, high amount of distillation residue



Substitute fuel

Selection of real components to characterize pyrolysis oil mixtures

Objectives:
- Small number of components representing the evaporation behavior of the technical fuel

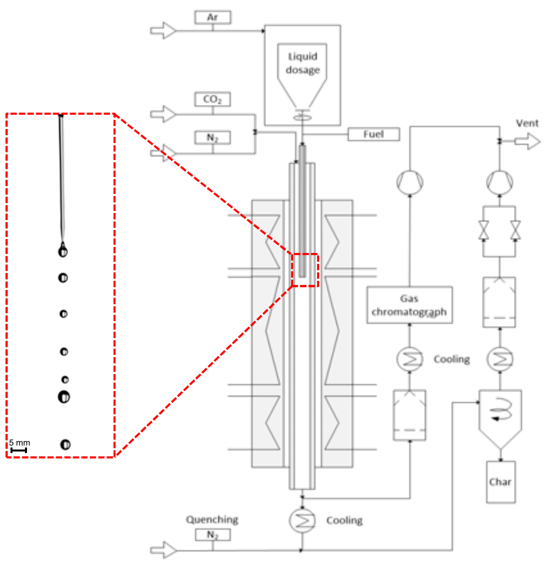
Implementation:
- Identification of components based on the distillation curve of pyrolysis oil
- Selection of type and amount of component by fractional distillation of boiling range and fraction analysis

Experimental Setup

Droptube Reactor

System Properties:

- p_{sys} = 1 bar (abs)
- T_{max} = up to 1700 °C
- Isothermal zone: 900 mm
- Inner diameter: 70 mmm
- Gas atmosphere: N_2, CO_2, Ar, syn. Air
- Gas analytics: FID µGC
- Solid sampling



Parameters of interest for Model Validation

- Composition of gas phase
- Droplet size and shape over time course
- Droplet surface temperature
- Conversion of pyrolysis oil to gaseous and solid fractions depends on:
  - Reactor temperature
  - Residence time
  - Fuel composition
- Formation of solid residue for characterization

Modelling of Multicomponent Evaporation and Solid Formation

Model based description

Numerical model for the evaporation and secondary pyrolysis of a single droplet under inert atmosphere

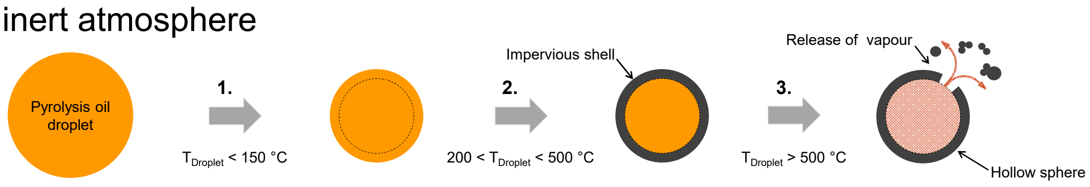


Fig.: Single steps of the conversion of pyrolysis oil; [1]

1. Surface Regression
- Evaporation of light volatiles at liquid surface
- Accumulation of heavy hydrocarbons in surface-near area

2. Bubbling/Swelling
- Formation of impervious shell
- Cracking and polymerization of compounds due to temperature increase at outer shell

3. Formation of Solid
- Solidification of outer shell
- Release of enclosured vapor creates hollow cenosphere

Characterization of Cenospheres

Conclusion about the solid formation mechanism and drying of Cenosphere

Parameters of interest
- Composition and morphology
- Shape and size of cenosphere

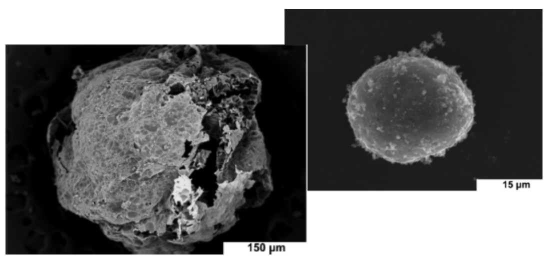


Fig.: SEM images of straw oil cenospheres; [2]

[1] **Hallett, W.; Clark, N.** (2005): *A model for the evaporation of biomass pyrolysis oil droplets.*
[2] **Stoesser, P. et al.** (2016): *Contribution to the Understanding of Secondary Pyrolysis of Biomass-Based Slurry under Entrained-Flow Gasification Conditions.*