Pyrolysis of torrefied material: Experiences and implications for practice

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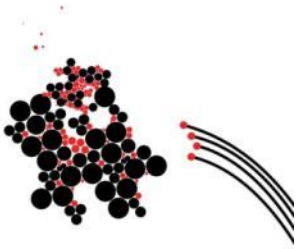
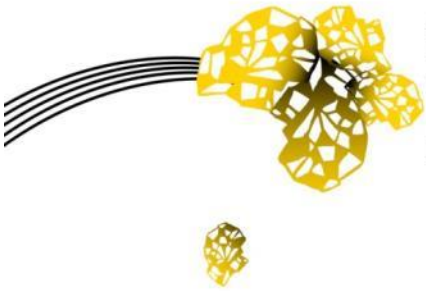


PYROLYSIS OF TORREFIED MATERIAL

EXPERIENCES AND IMPLICATIONS FOR PRACTICE



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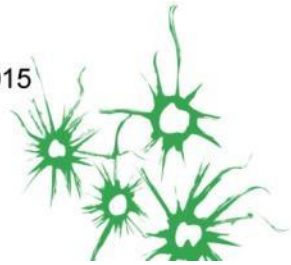
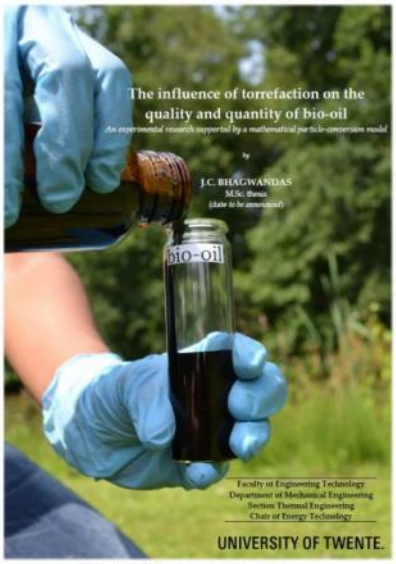


WHY PYROLYSIS?



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WHY PYROLYSIS?

- Simple process, mild conditions
- Energy densification
- Thermal cleaning, separation of minerals from ashes

- Applications:
  - Drop-in fuel for refineries (green chemicals)
  - Upgrading to advanced bio-fuels
  - Production of clean power and heat (turbine, engine, boiler)

WHY TORREFACTION PRE-TREATMENT FOR PYROLYSIS?

- Drivers: increased quantity and quality
  1. Easier grinding, smaller particles lead to higher oil yields
  2. Hemicellulose (acid precursor) removal leads to better oil quality
  3. Storage / bio-degradation

ASSESSMENT OF IMPACT OF TORREFACTION

- Experimental goals:
  - Investigate influence on decomposition rate
  - Improvement of the oil quality
- Variables:
  - Biomass type (softwood, hardwood, waste wood, straw)
  - Torrefaction degree/severity
  - Chips vs. pellets

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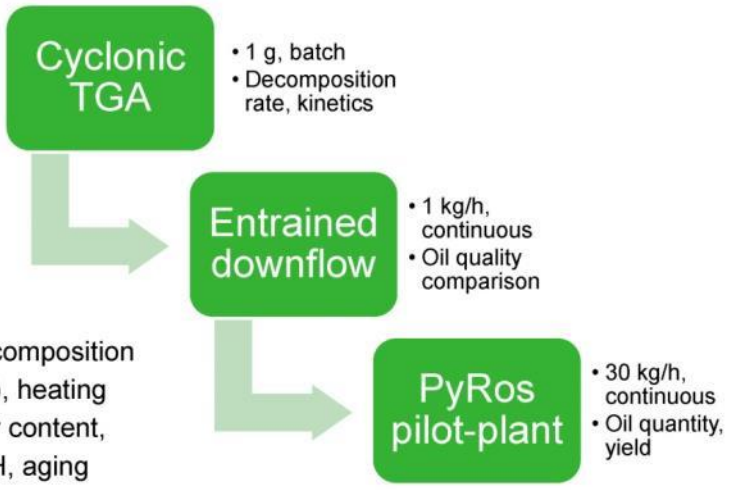
ASSESSMENT OF IMPACT OF TORREFACTION

- Methods:



- Oil quality: composition (O_2-content), heating value, water content, viscosity, pH, aging

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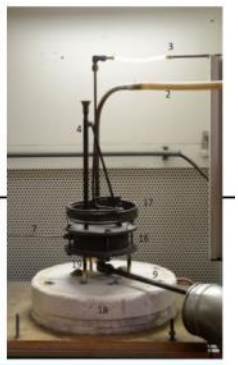
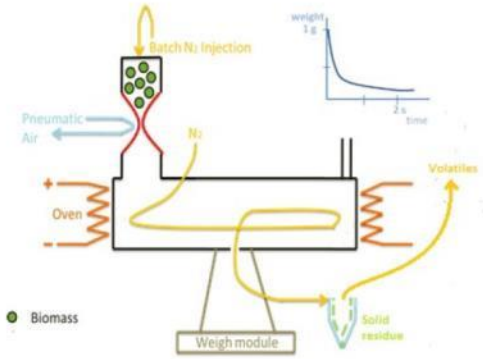
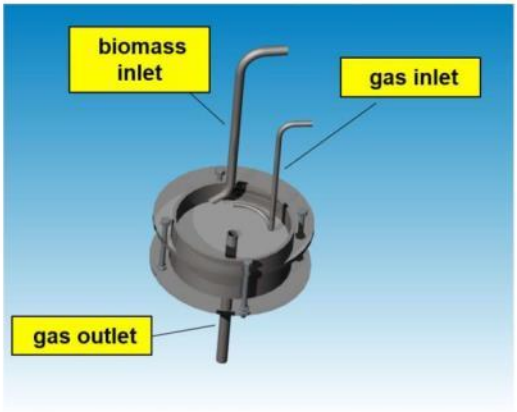
ASSESSMENT OF IMPACT OF TORREFACTION
CYCLONIC TGA



- Cyclonic TGA: mimics flash pyrolysis conditions
- Measuring decomposition mass change over time





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ASSESSMENT OF IMPACT OF TORREFACTION
CYCLONIC TGA

- Results cyclonic TGA:
  1. Lower reaction rate (up to 30%) of torrefied material
     - Volatile part removed during torrefaction
       - Confirmed by TG/DTG data
     - Typical reaction time = 1.5-2s (virgin) and 2-2.5s (torr)
     - Used to optimize residence times in pyrolysis reactors
  2. Differences in reaction rate dominated by hemicellulose content
     - Straw > hardwood > softwood
  3. Reaction rate pellets 10% lower than chips

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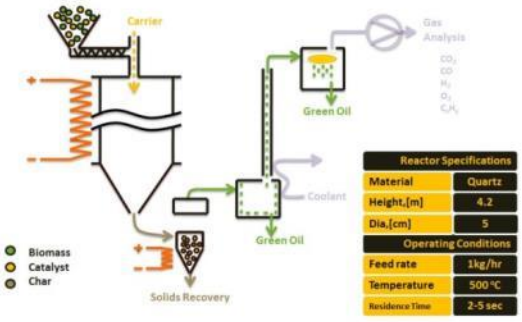
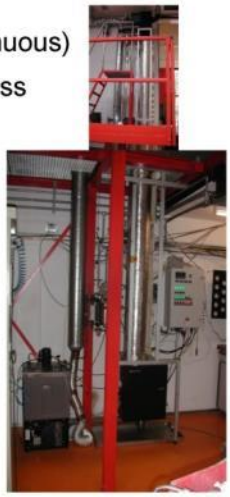
ASSESSMENT OF IMPACT OF TORREFACTION
ENTRAINED DOWNFLOW SETUP

- Entrained downflow setup: bio-oil production (continuous)
- Comparing oil qualities of virgin and torrefied biomass



Reactor Specifications	
Material	Quartz
Height,[m]	4.2
Dia,[cm]	5
Operating Conditions	
Feed rate	1kg/hr
Temperature	500 °C
Residence Time	2-5 sec



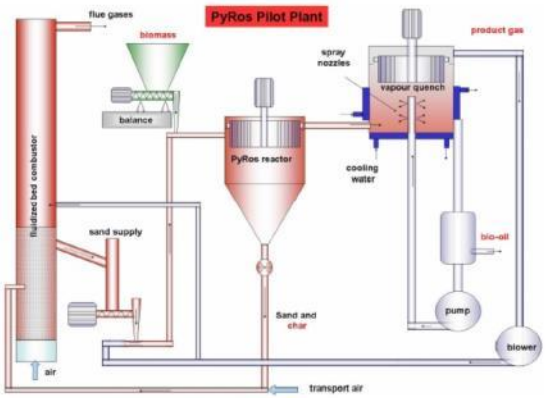
ASSESSMENT OF IMPACT OF TORREFACTION
ENTRAINED DOWNFLOW SETUP

- Results downer:
  1. Increased heating value (up to 20%)
     - Less water in oil (up to 25%)
  2. Decreased oxygen content (up to 20%)
  3. Decreased oil yield (up to 40%)

- Hardwood, softwood, mixed waste wood performed similarly
- Wheat straw oil yield down 90%, not recommended

ASSESSMENT OF IMPACT OF TORREFACTION
PYROS PILOT PLANT

- PyRos pilot plant, 30 kg/h
- Experiments with torrefied biomass



ASSESSMENT OF IMPACT OF TORREFACTION
PYROS PILOT PLANT

- Results PyRos:
  1. Oil quality improved
     - Heavy fraction contains low amount of O_2
     - Light fraction contains most of the water
  2. Higher oil yields than entrained downflow reactor
     - Due to more complete conversion
     - But still too low, room for improvement
  3. Biomass feeding very smoothly
     - More homogeneous material of the feed

CHAIN ANALYSIS

CHAIN ANALYSIS

1 Grinding → Drying → Pyrolysis η=62%

2 Torrefaction → Grinding → Pyrolysis η=68%

- Assumption: torrefied wood (280°C, 45 mins)

- Grinding energy 85% down
- Yield oil 40% down
- Heating value oil 20% up

- Oxygen in oil 20% down → η=57% vs. η=68%

Further assumptions	Values
HHV biomass (DAF)	20,6 MJ/kg
HHV torr biomass (DAF)	23,0 MJ/kg
H_2O biomass	6,3%
H_2O torr biomass	1,8%
Biomass oil yield	47%
Torr biomass oil yield	33%
Grinding biomass	850 kWh/t
Grinding torr biomass	100 kWh/t
Heat of reaction pyrolysis	0 MJ/kg
Heat of reaction torrefaction	0 MJ/kg

CONCLUSIONS & IMPLICATIONS FOR PRACTICE

- C-TGA/kinetics: longer reaction time needs optimization of pyrolysis process design
  - Depending on T, ~0.5-1s longer
- Oil comparison: improved oil quality
- Oil yield: should be improved (process optimization)
- Chain analysis: improved energy efficiency

→ Pyrolysis is a viable application of torrefied material

→ Processes can be further optimized to improve performance

→ Pyrolyzing torrefied material makes the biomass available for gas-fired boilers / power plants in addition to wood-fired boilers