Fluidized bed pyrolysis of lignin in a bubbling bed reactor

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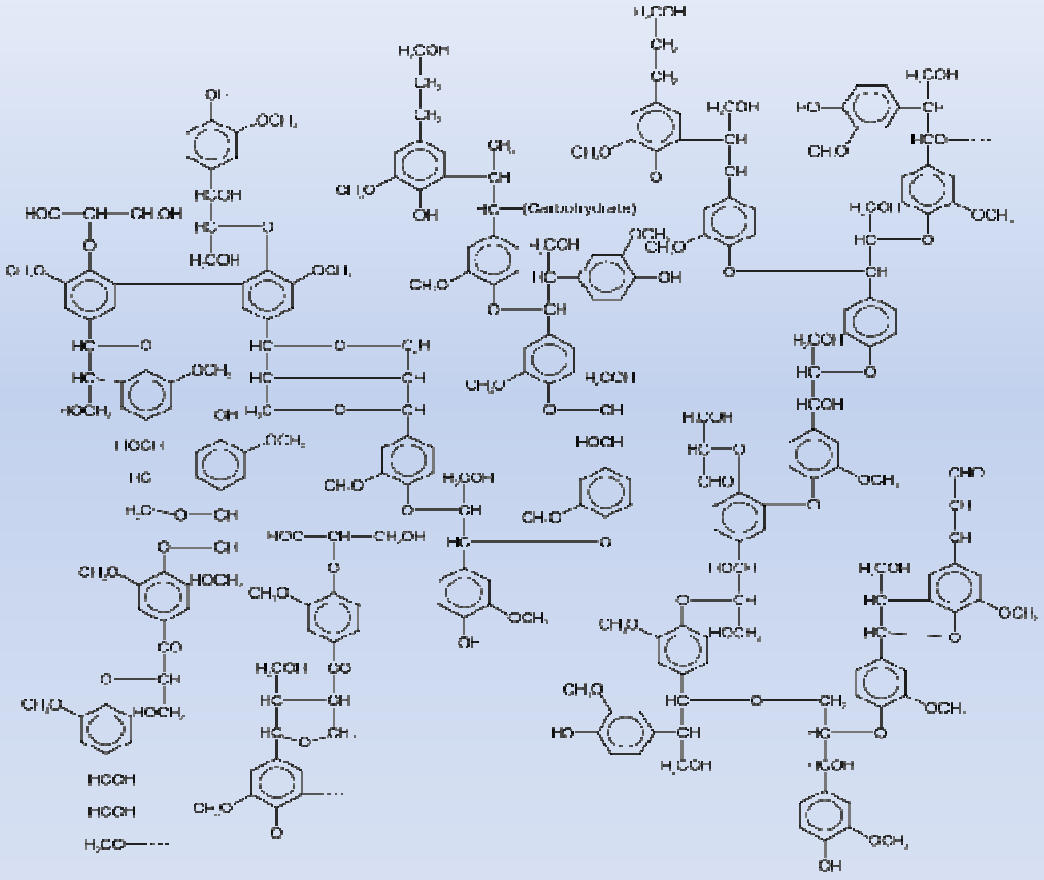
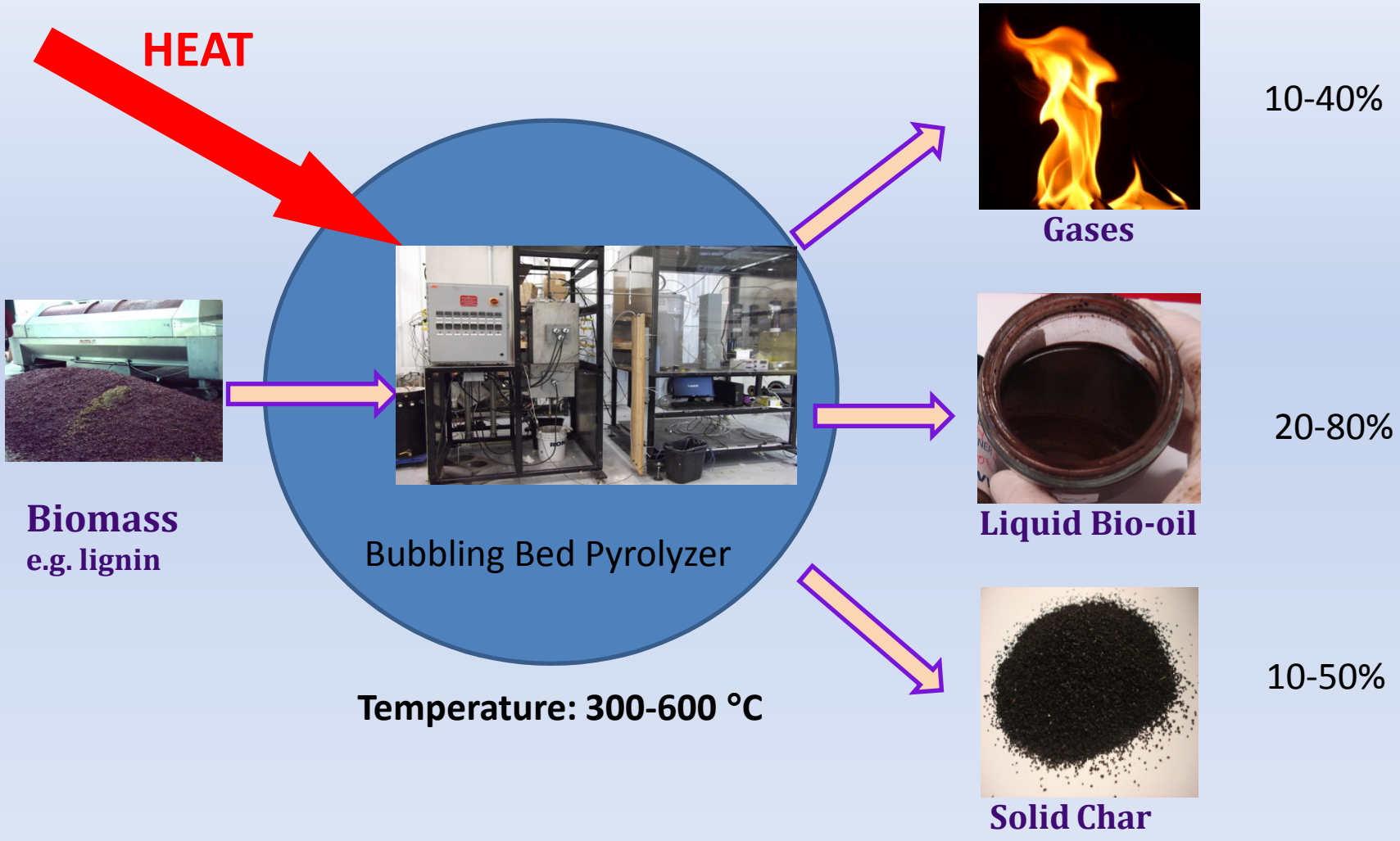
What is lignin?



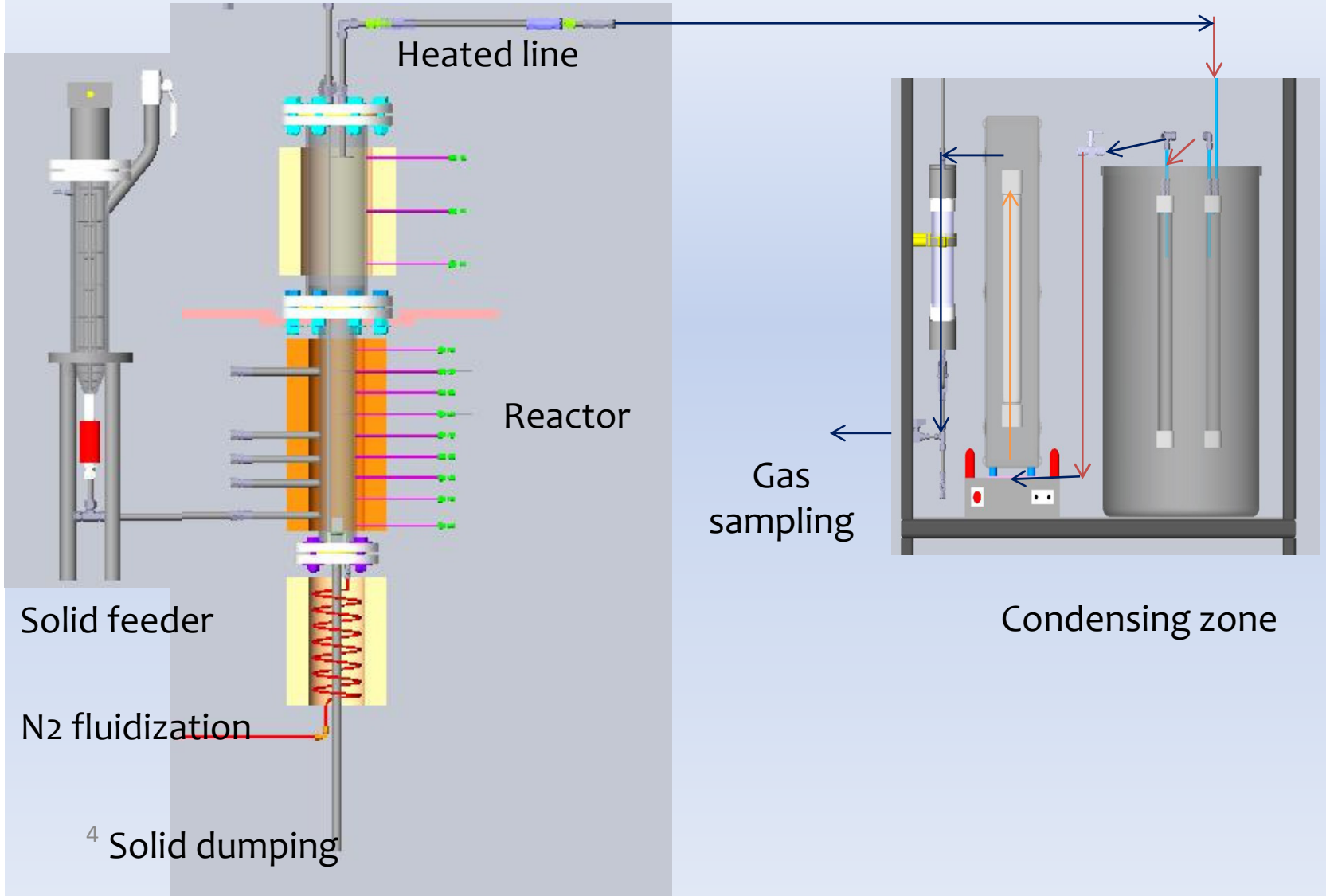
Lignin is a complex chemical compound chemical most commonly derived from wood (now considered a sort of by-product for the production of cellulose).

It is the most important natural polymer actually used like fuel, could be used as chemicals source (alternative to the crude oil), for this reason there are many research project in the world about its cracking.

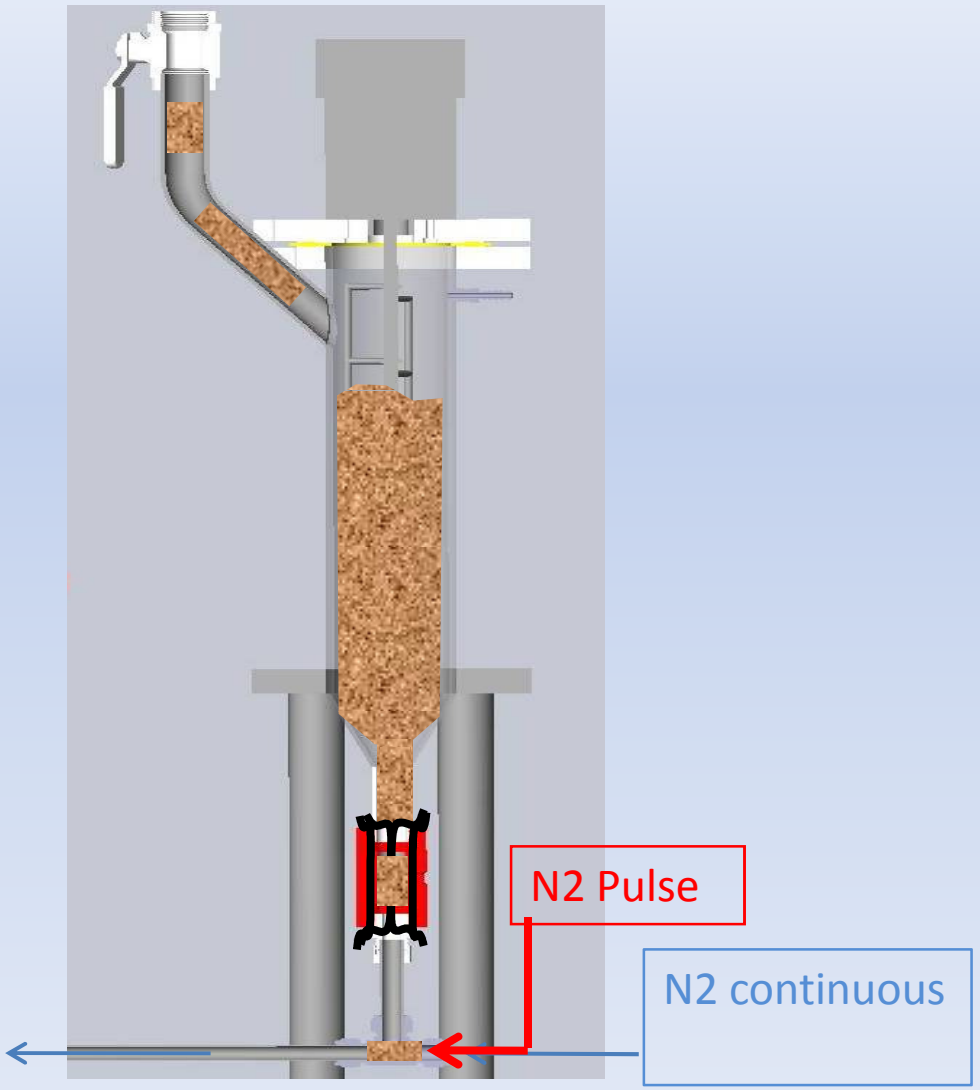
Flash Pyrolysis:
Conversion of Biomass into Bio-oil and Bio-char



Experimental Apparatus: Continuous System



Experimental Apparatus: Continuous System Feeding



Pyrolysis Reactor and Operating Parameters in Continuous System

Vapour residence time = 2 s

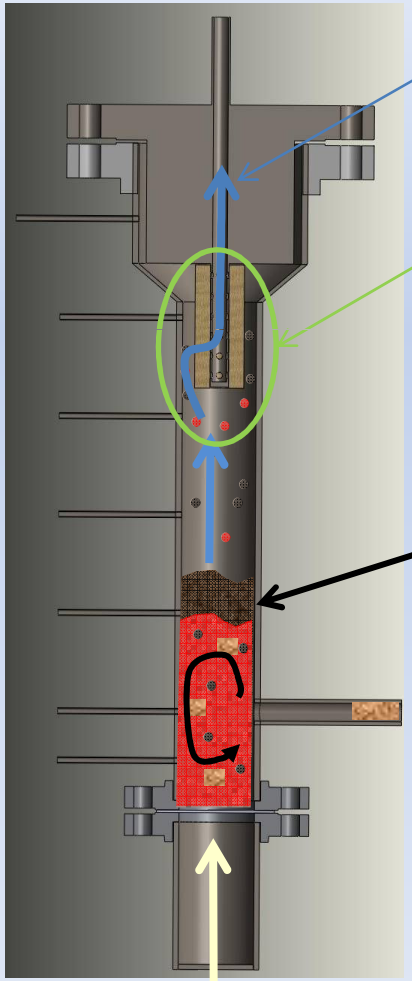
Reactor section = 7.5 cm

Reactor volume = 2.8 liters

Sand weight = 1.5 kg

Sand d_{psm} = 180 μm

Biomass injection rate = 1 kg/hr



Bio-oil vapours and gases

Hot filter traps fine char particles

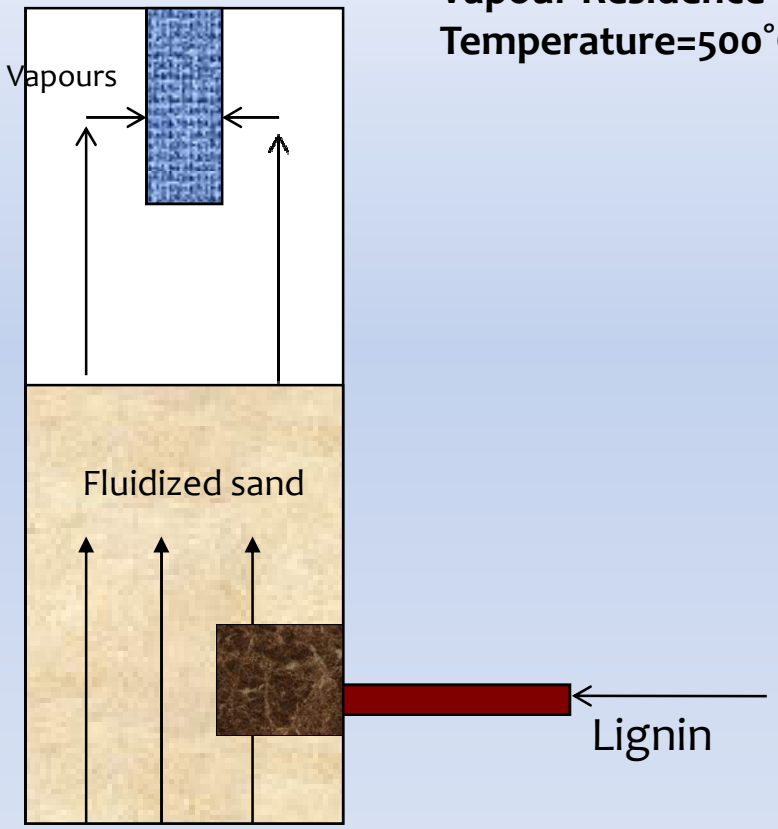
The char stays in the bed

Biomass injection

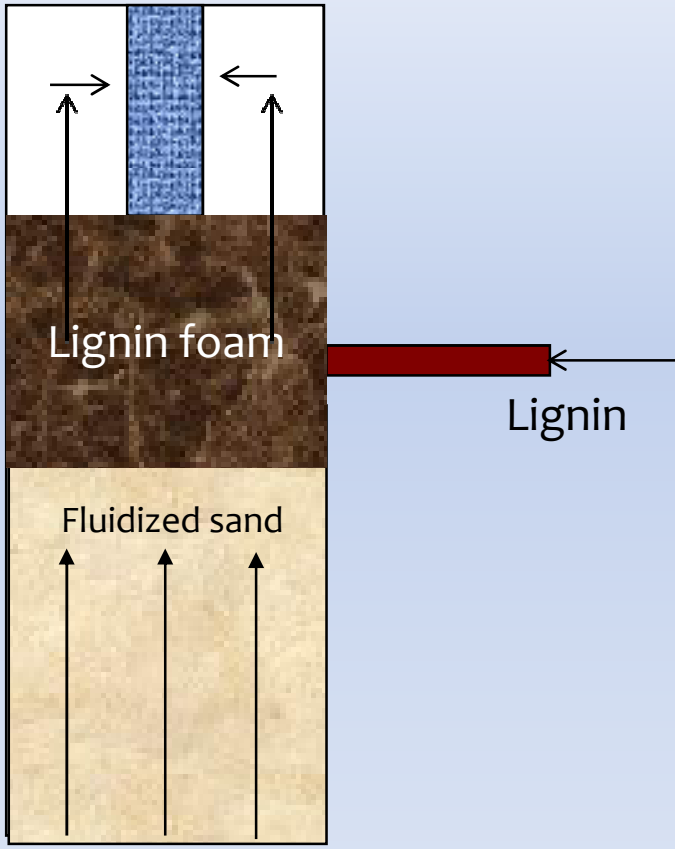
N_2 or Recycled pyrolysis permanent gases

Experimental Results Continuous System: Feeding line: bottom or freeboard?

Vapour Residence time =2 s
Temperature=500˚C-650˚C



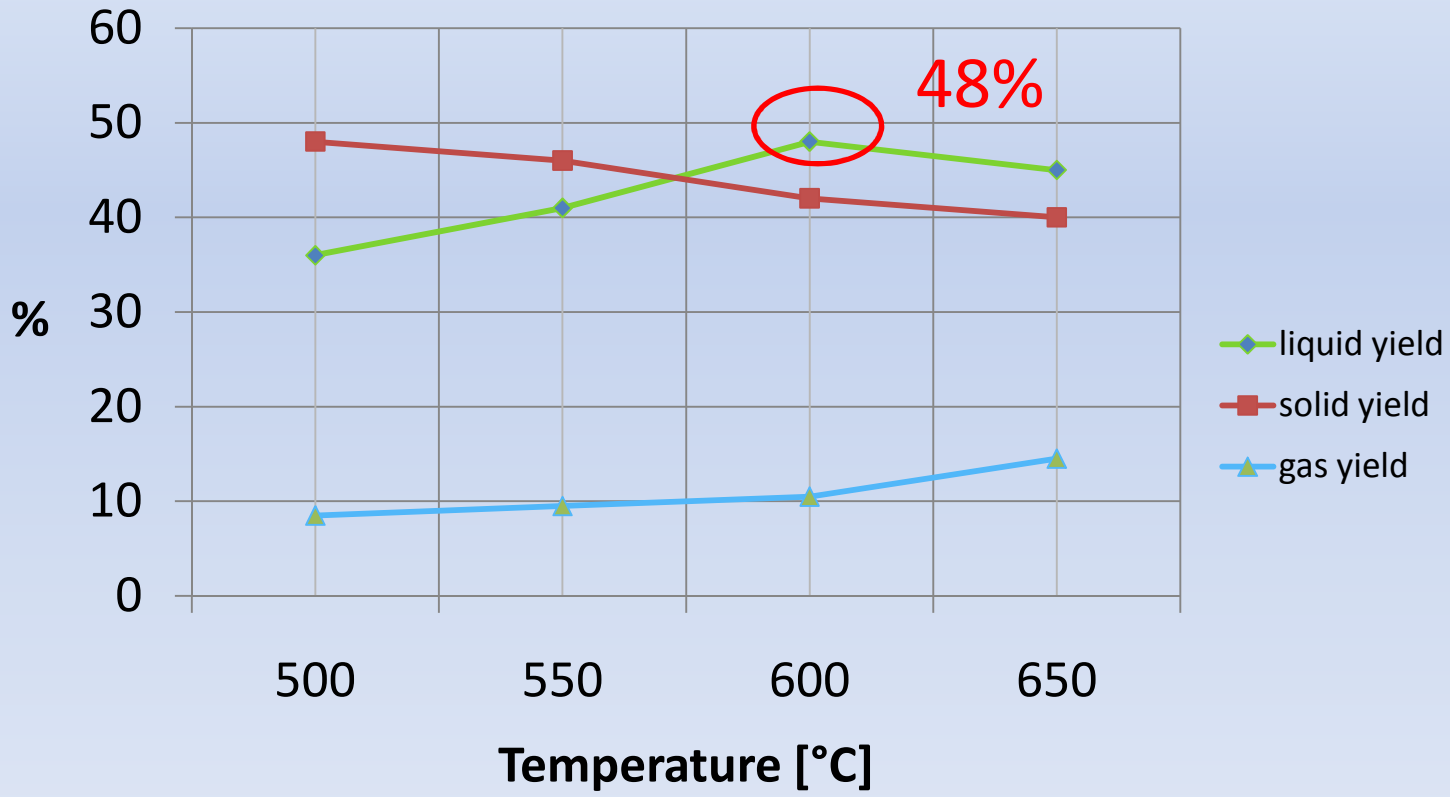
Reactor and feeding line *plugged* after few pulses of lignin injection



With this setup, 200g of lignin fed in 12 minutes.

Test run with freeboard feeding

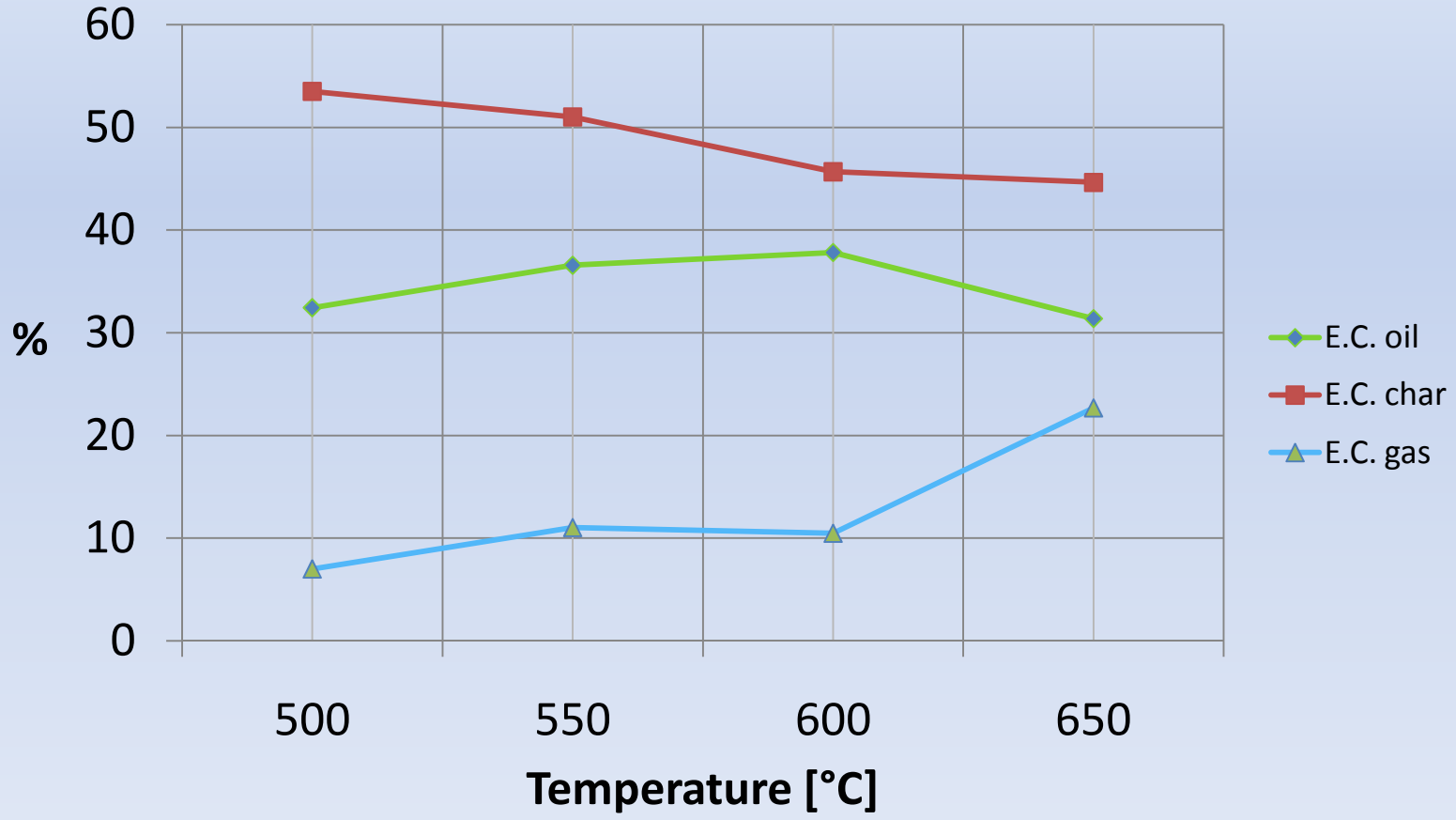
SOLID, LIQUID AND GAS YIELD



Test run with freeboard feeding

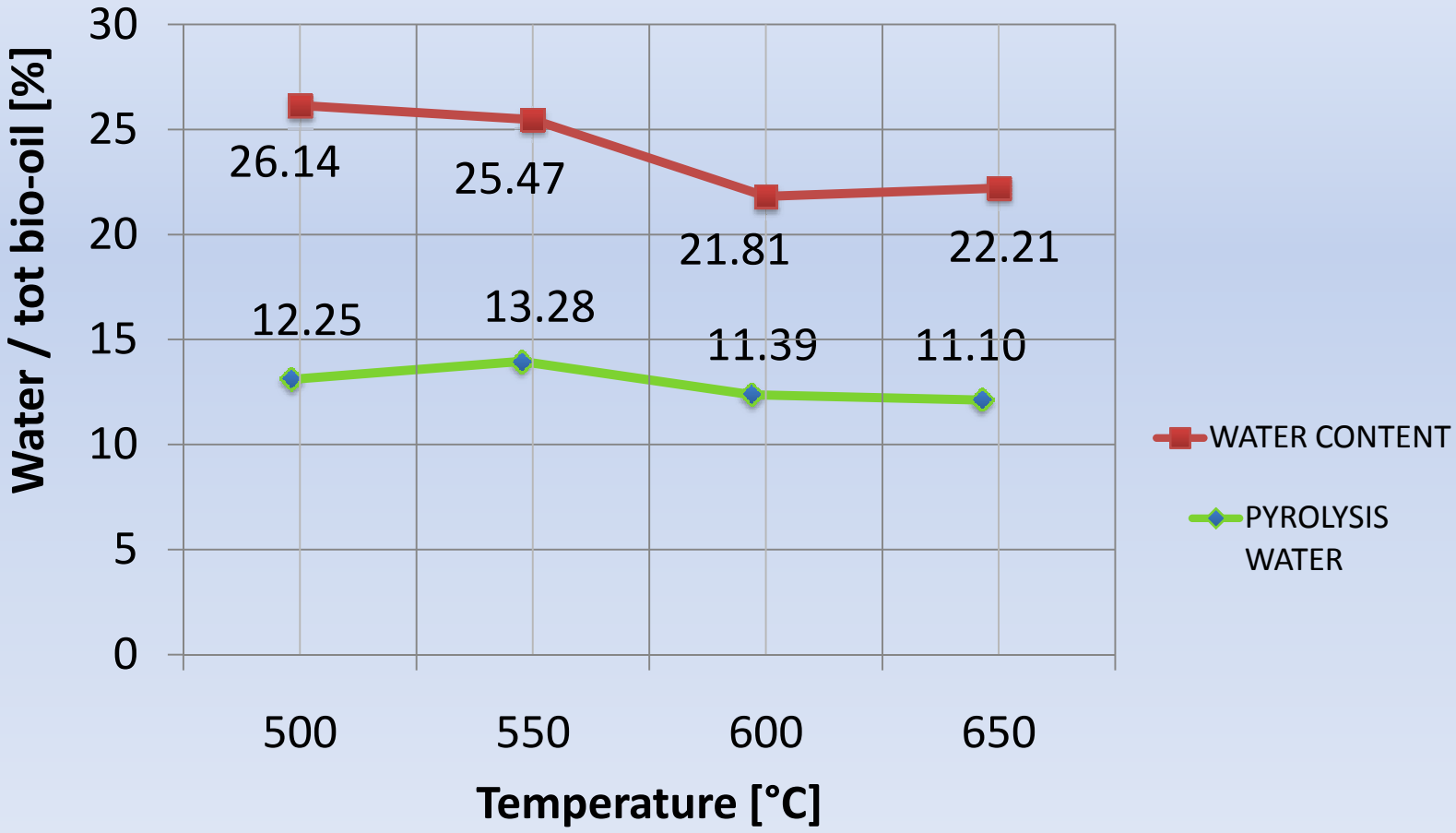
ENERGY CONVERSION

LIGNIN LHV= 26 kJ/g



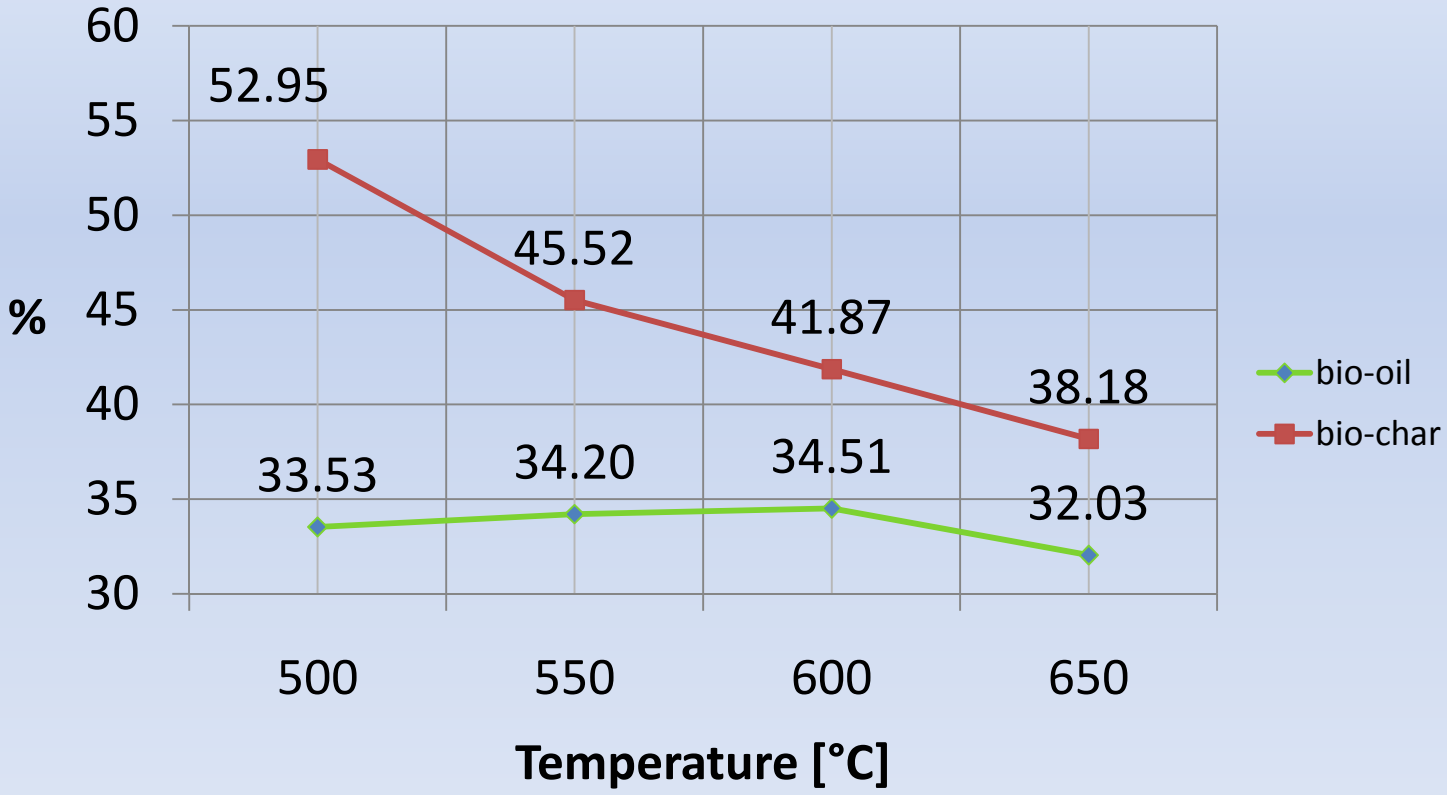
Test run with freeboard feeding

WATER CONTENT



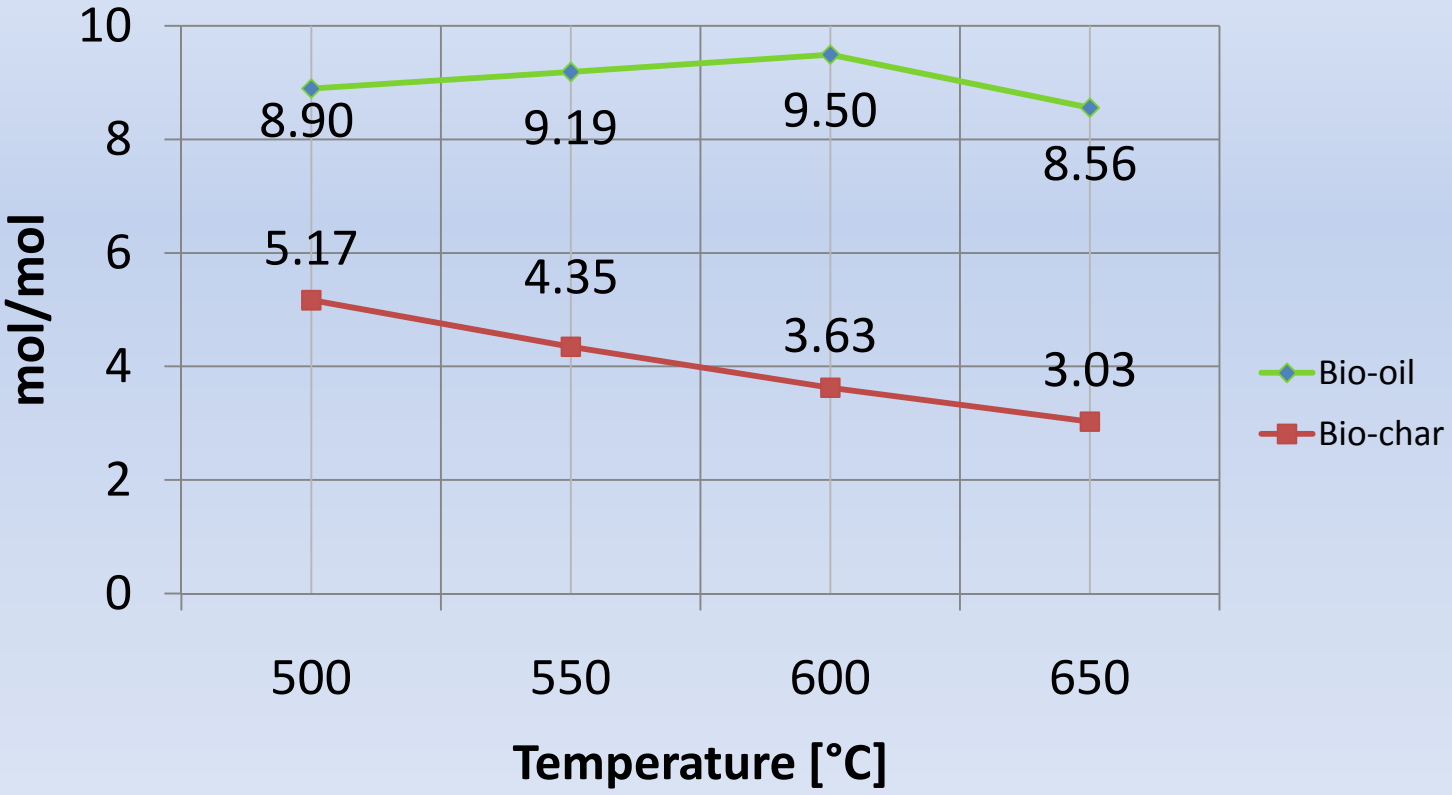
Test run with freeboard feeding

CARBON CONTENT



TEST RUNS WITH FREEBOARD FEEDING

H/C MOLAR RATIO

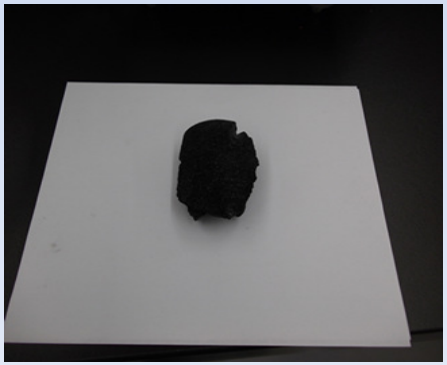


Problems with continuous system

- Lignin starts melting at low temperature:
  - Even the pulsed feeder plugs
  - Hinders contact between hot sand and lignin particles: pyrolysis is not very fast

- Low density lignin foam:
  - Floats on top of the bed and plugs reactor
  - Hinders fast heat transfer to reacting lignin: pyrolysis is not very fast

→ Could not produce large amounts of lignin bio-oil



Lignin injected = 200 g in 12 minutes in the freeboard

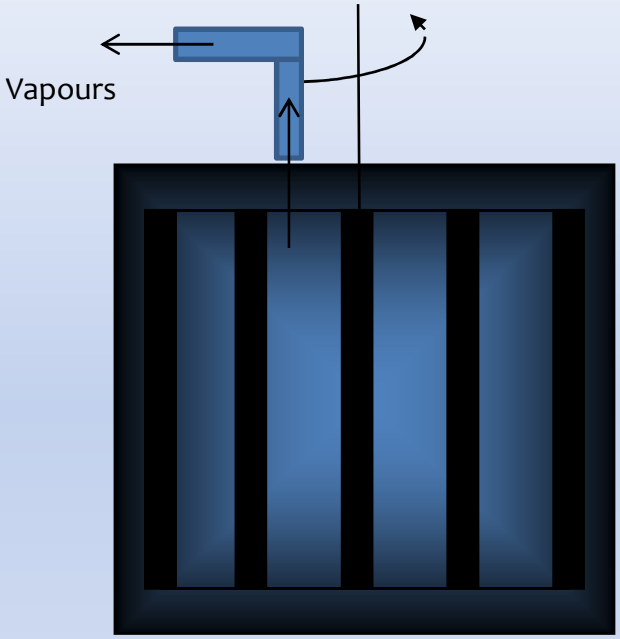
Bio-char presents a solid sponge form

Density of char = 0.20 g/cm^3

Density of lignin = 0.33 g/cm^3

Batch System:
Mechanical Fluidized Reactor

MFR: BATCH SYSTEM



T= 25-500 °C in 2 h

No gas fluidization

No foam after reaction

Reactor volume: 3 liters

Lignin / (inert bed particles) = 1/5 wt/wt

- Mechanical mixing destroys the lignin sponge, promoting good contact between FCC and char.
- The MFR would not be easy to scale up.

Solutions for continuous system

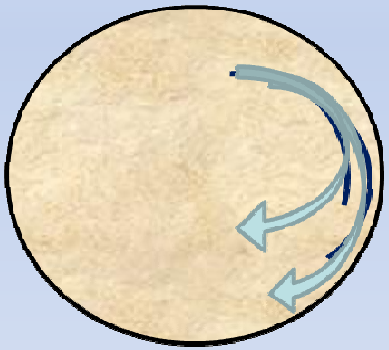
Solutions that could be implemented in scaled-up units:

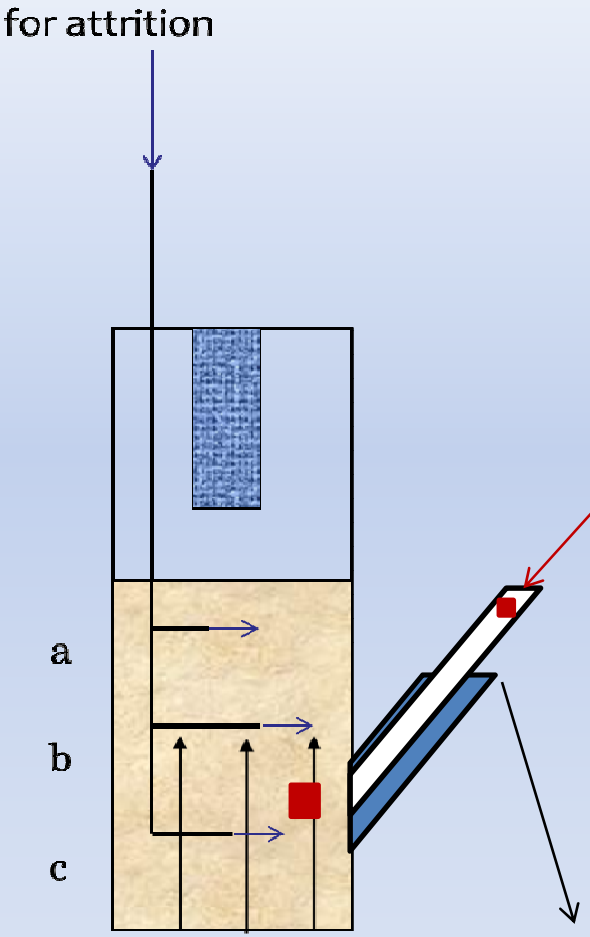
- Lignin starts melting at low temperature:
  → Changed feeding pipe location:
  - above the bed and inclined downward
  → lignin has to be injected down into the bed
  → Feeding pipe jacketed for cooling

- Low density lignin foam:
  → Supersonic attrition jets break up the foam
  → Jets swirl the bed to enhance heat transfer

Continuous System Implementation: cooled feeding line, internal swirling attrition jet

Swirling attrition jets





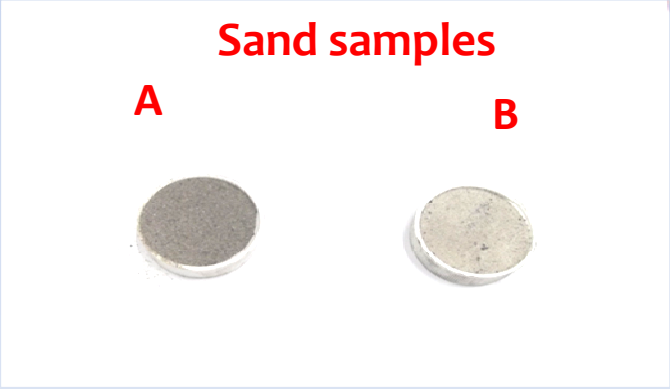
The lignin can be easily fed in the bubbling bed, the temperature of the feeding line is below 200˚C

New Continuous System: Preliminary results

- Biomass injected = 200 g (bio-oil and biochar collected) over 1.5 kg of sand
- Feeding (cooled) line: ok
- Bio-char foam partially destroyed
- The swirling attrition jets provide good mixing but could not completely destroy the foam
- Fine biochar particles are well mixed with the sand

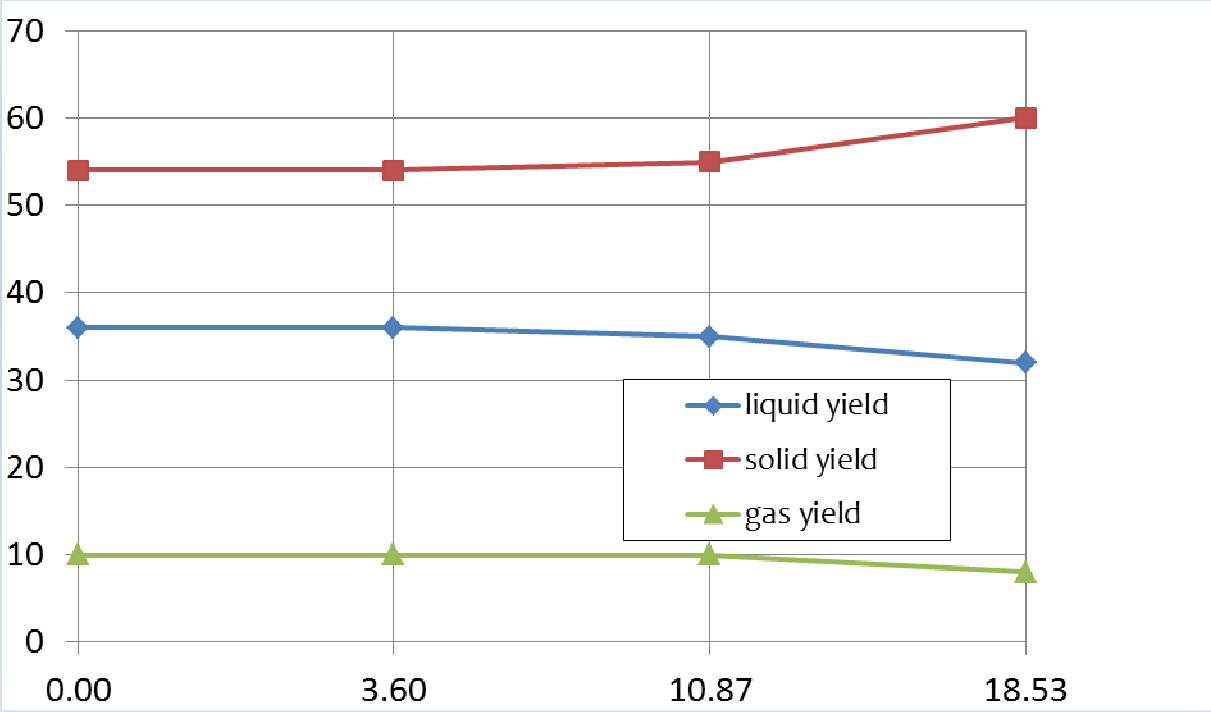
Continuous reactor with swirling attrition jet

Continuous reactor without attrition jet



New Continuous System: Effect of the char concentration vs Yields

Temperature operation : 500°C
Vapour residence time 1sec
Lignin fed for each run: 100g



If the char concentration increases its value into the fluidized bed,
we will achieve lower gas and liquid yields (keeping constant temperature and vapour residence time) higher solid yields.

"char makes char"

Conclusions and future works:

The Lignin pyrolysis using a bubbling bed reactor has been studied and experimented in several projects with not good results. The present work can suggest some solutions about a pilot plant, interesting in a future scaling up.

FEEDING LINE:

Feeding line in the freeboard (achieving a poor mixing with the hot sand) but biochar sponge foam formation.

Cooled and inclined feeding line at the bottom (good mixing, but not enough, with the hot sand)

IMPROVEMENT for MIXING and CHAR DESTRUCTION:

To achieve a good and strong interaction among sand, lignin and char, it is necessary to increase the force that the hot sand has to get the solid biochar particle destroyng (lighter than the sand, so floating above it during fluidization). In a batch system (mechanical fluidized reactor) the mechanical blades' agitator had enough force to destroy them reaching a good mixing. In order to have the same results, a swirling (internal) multiple attrition jets have been adopted, and it was partially able to destroy part of the sponge foam solid char. Solution that is even easily scalable up. In this case is strictly necessary the feeding line in the bottom of the bed (with a cooled system).

Acknowledgements

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Thanks for your kind attention