Coal and biomass bubbling fluidized bed gasifier - design and operation

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Outline

- Motivation
- Objectives
- Experimental setup
- Material characteristics
- Results
- Conclusions
- Future work

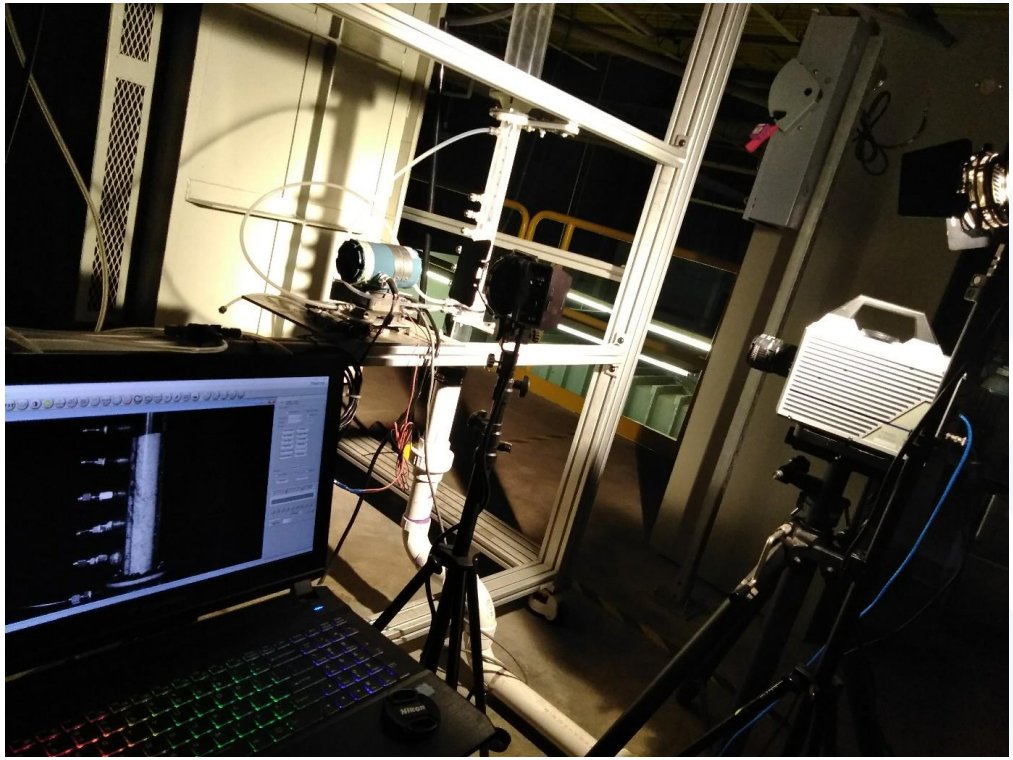
Motivation

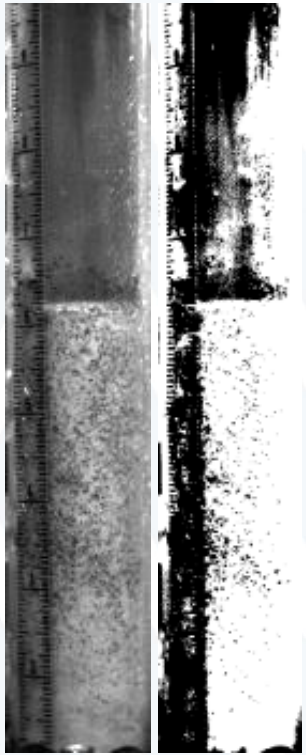
- Efficient use of conventional and alternative energy resources
- Bubbling fluidized bed gasifier (BFBG) can convert biomass and coal into value-added chemicals and gaseous fuels for transportation or electricity generation
- Understanding the parameters that affect the fluidization hydrodynamics
- Collect experimental data representative of optimum conditions and use it to develop numerical simulations

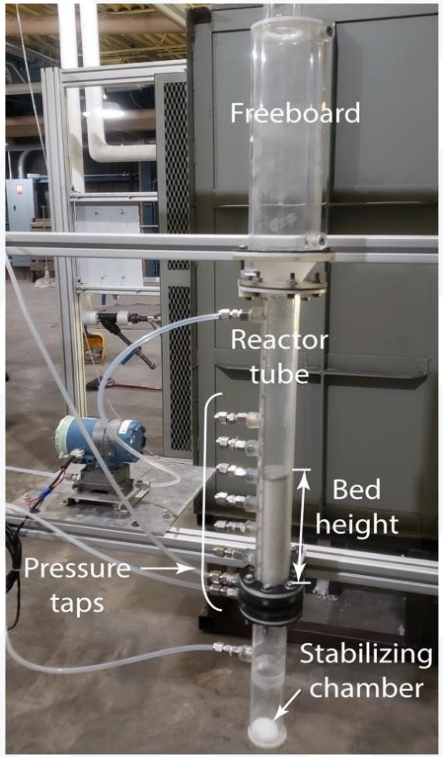
Objectives

- Design and manufacture a BFBG that will help MFIX code development
- Investigate parameters that affect fluidization hydrodynamics
- Investigate coal and biomass and coal gasification
  - Efficiency
  - Product composition
- Collect data for model development

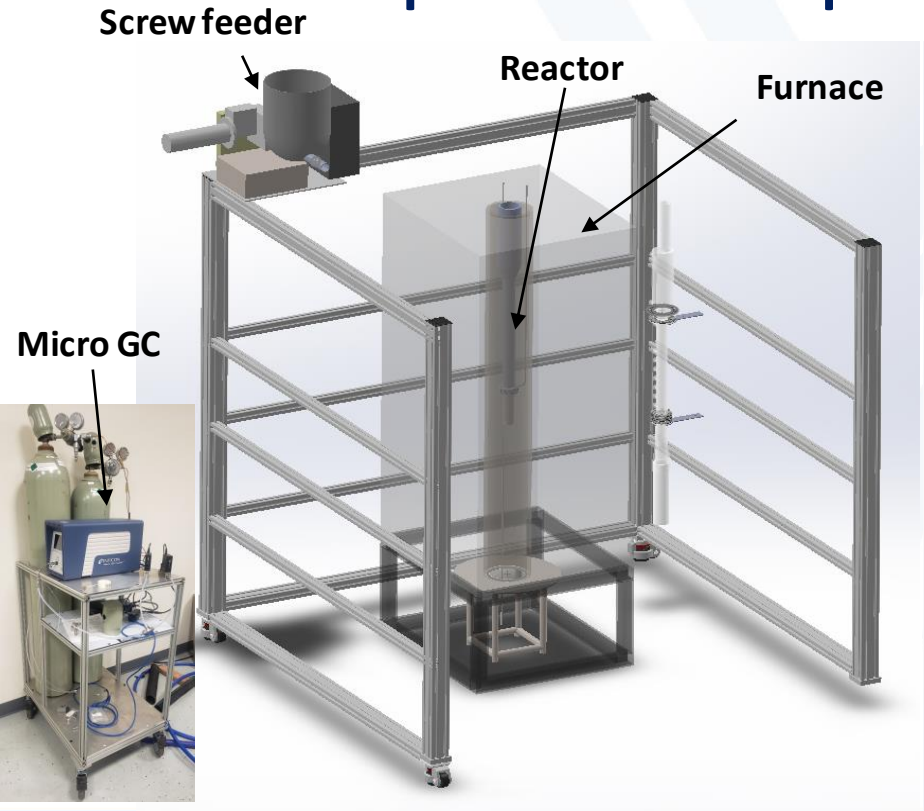
Experimental setup - Cold flow visualization and measurements



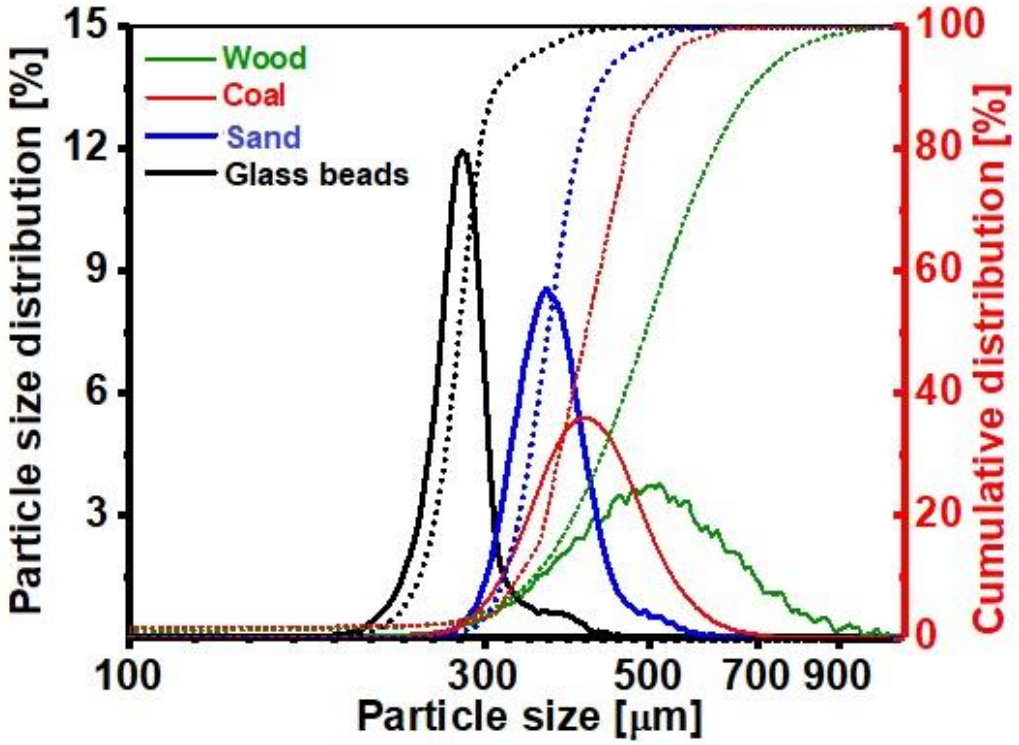




Experimental setup – BFBG at high temperatures



Particle geometry



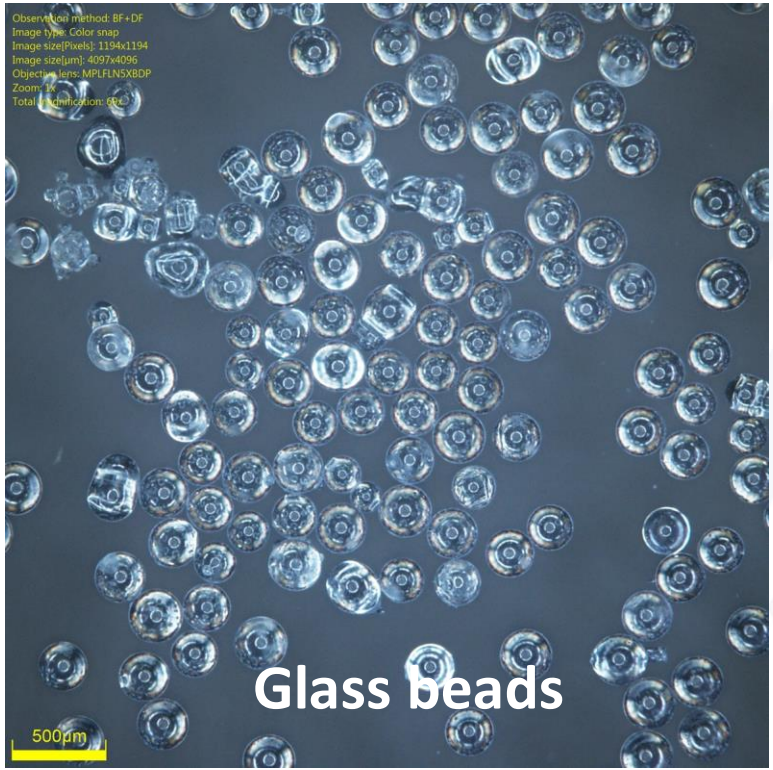
- Particle size and sphericity distribution affects the efficiency and product gas composition
- Important for correct process simulation

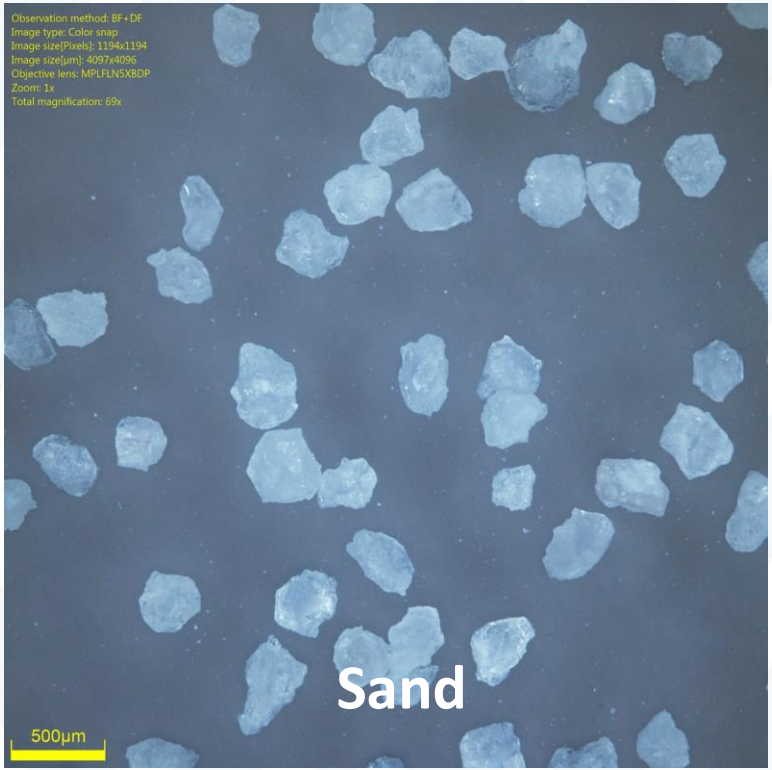
Material Characteristics

Table 1. Material size and sphericity analysis

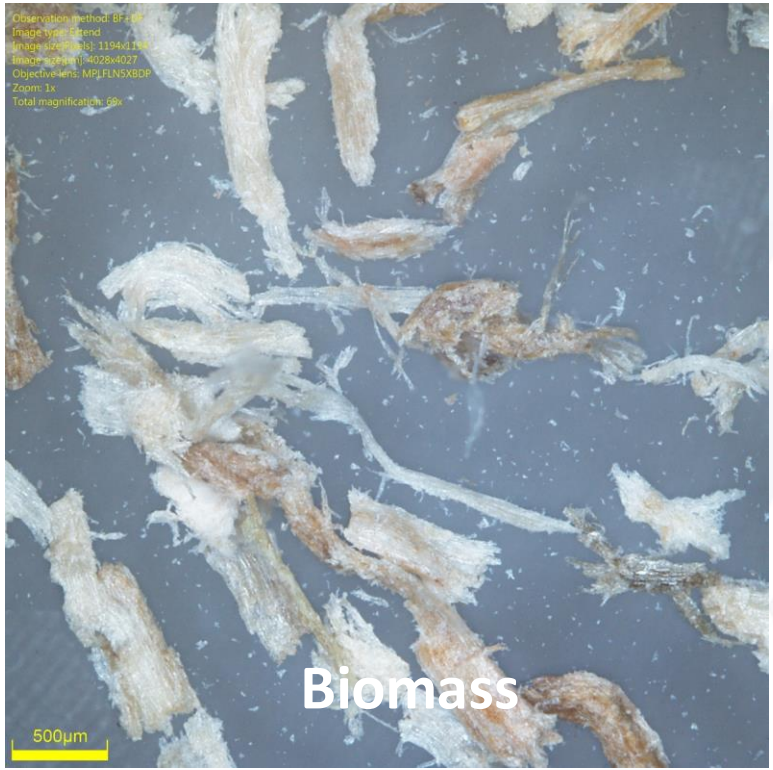
Material	Average of particle size (μm)	Average of Sphericity
Hardwood	432	0.564
Coal	361	0.847
Glass beads	279	0.933
Sand	368	0.863

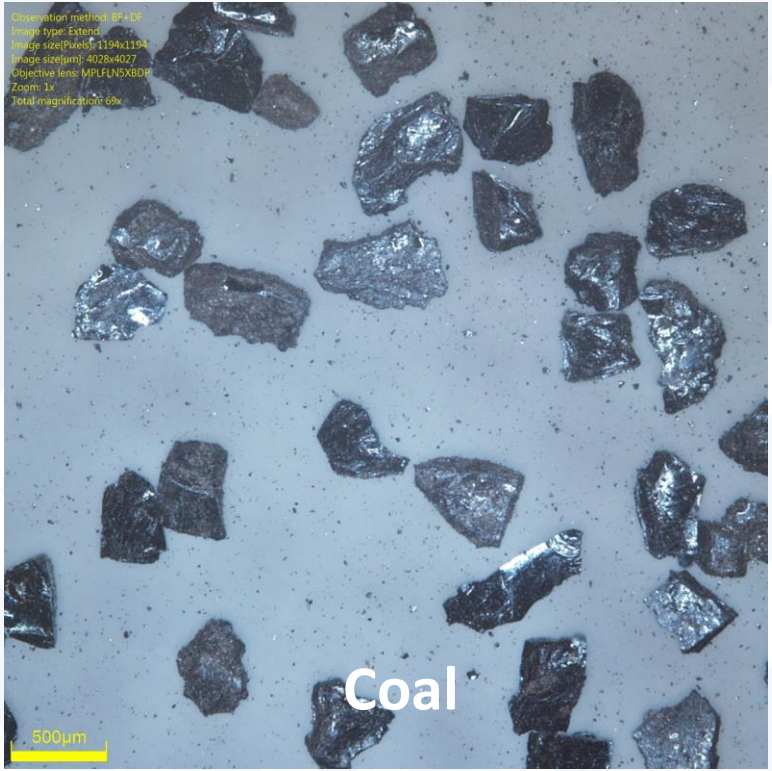
Close-up of bed material geometry



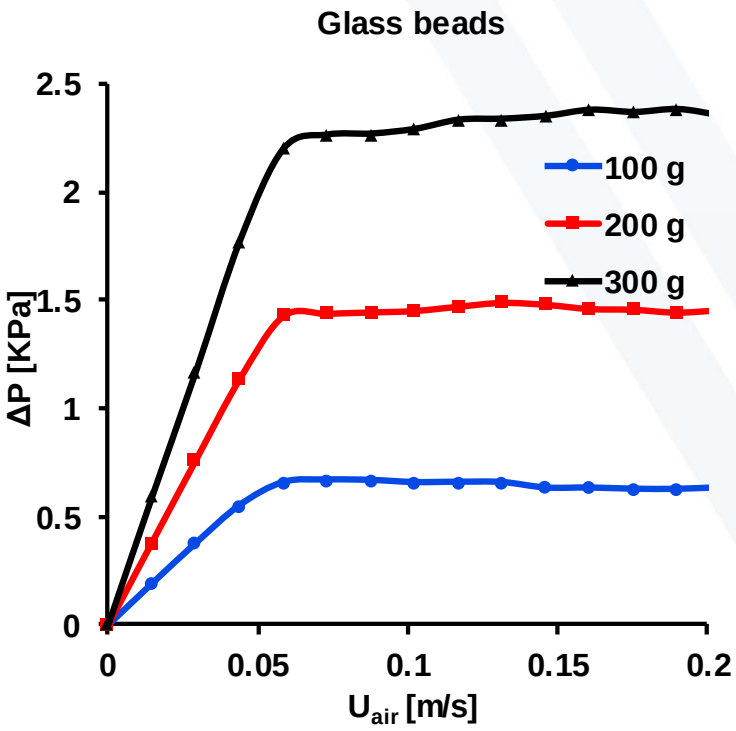


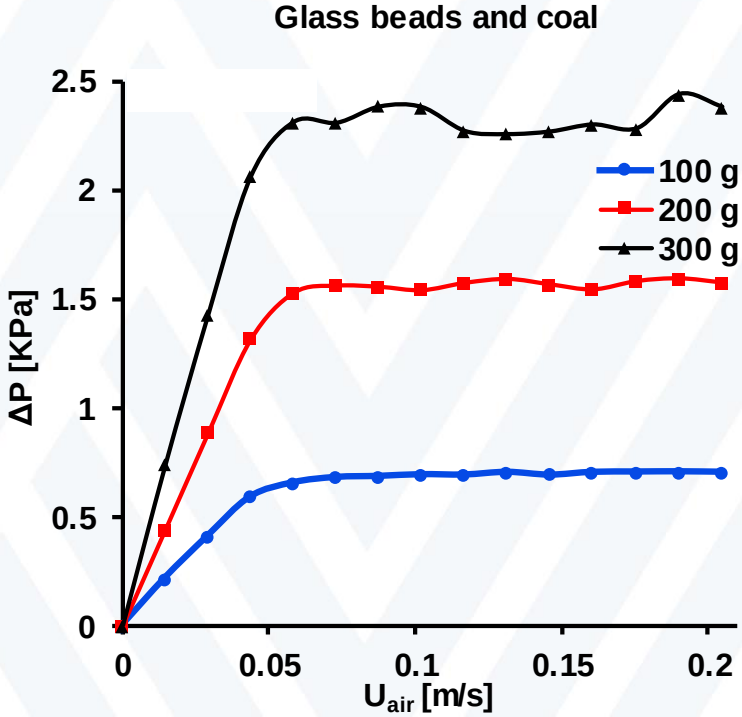
Close-up of fuel material geometry





Results: Pressure drop across the bed - cold flow





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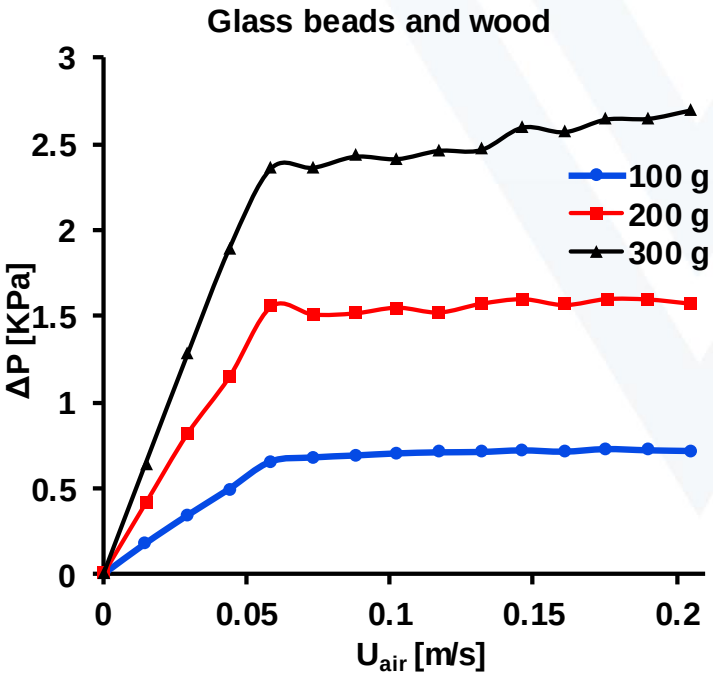
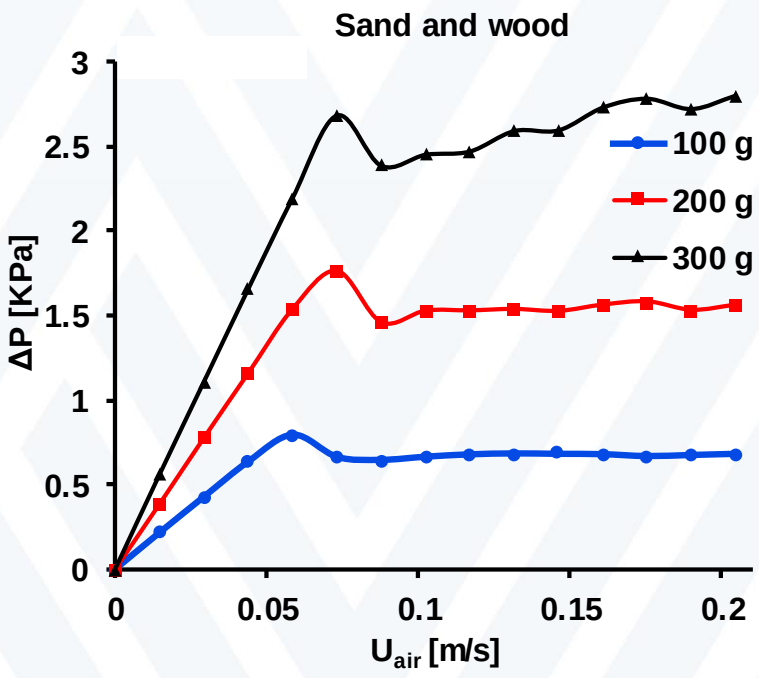
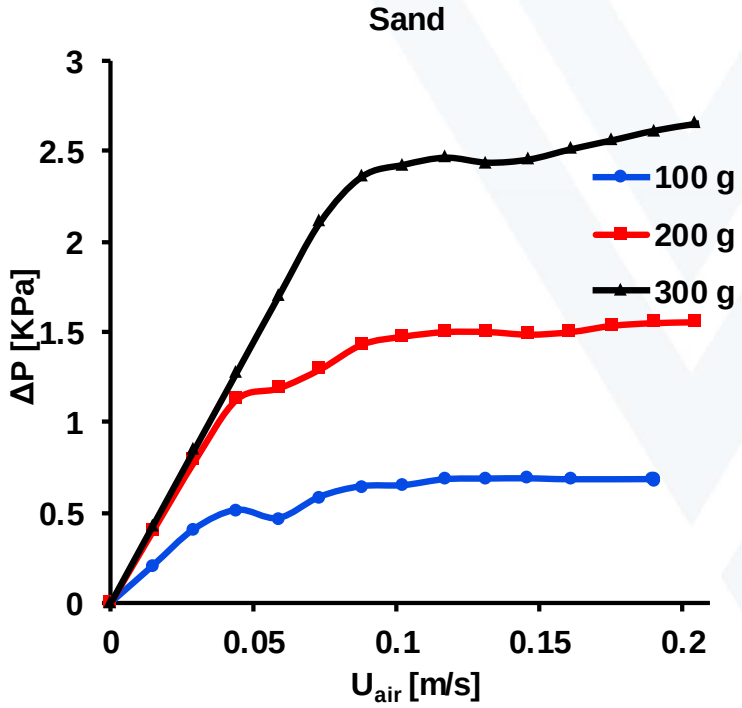
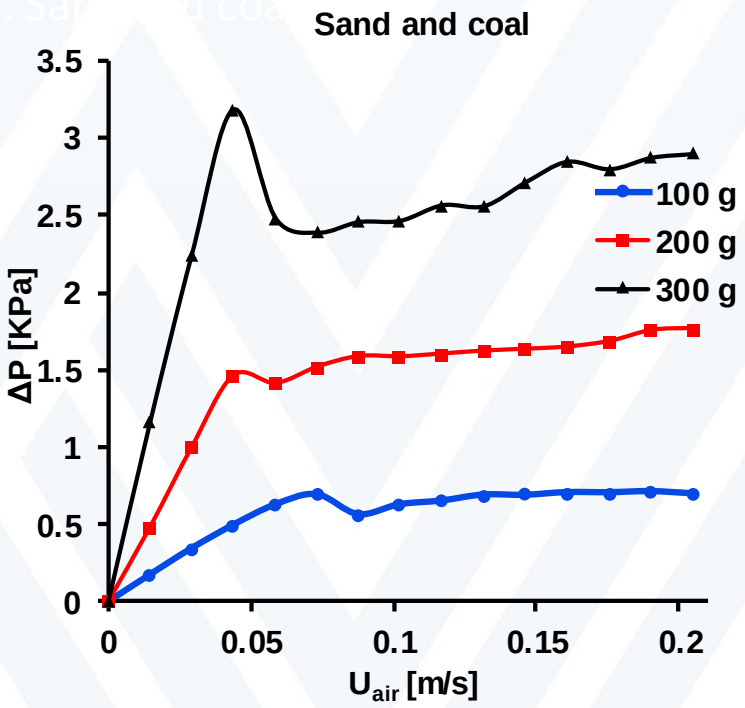


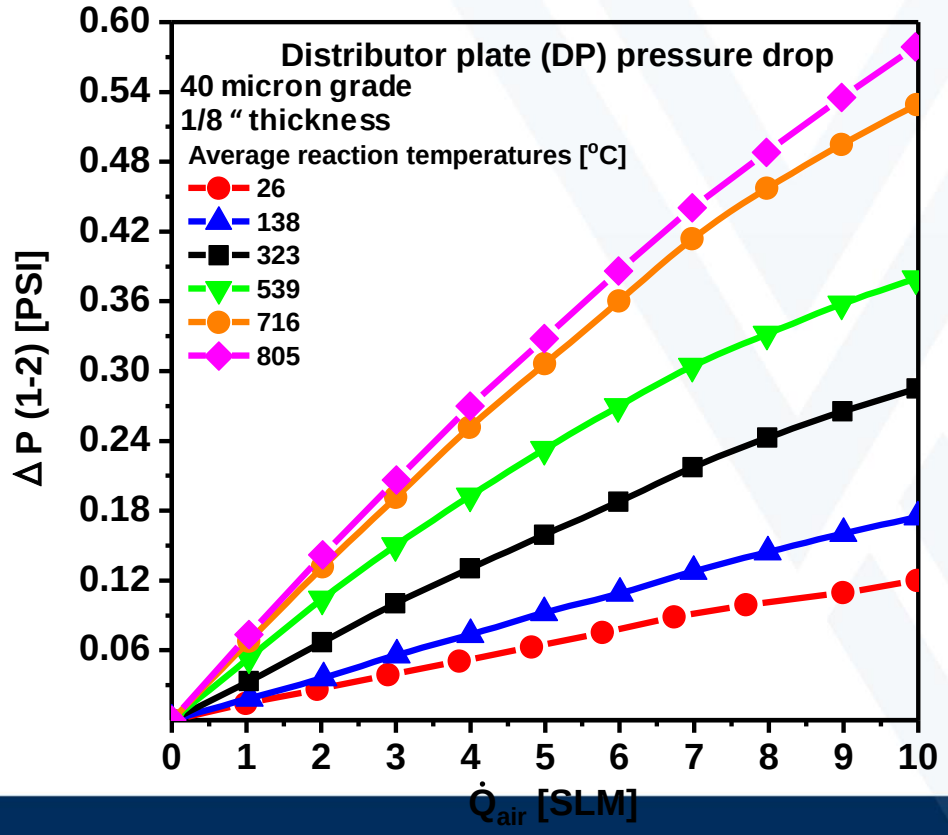


Results: Pressure drop across the bed - cold flow



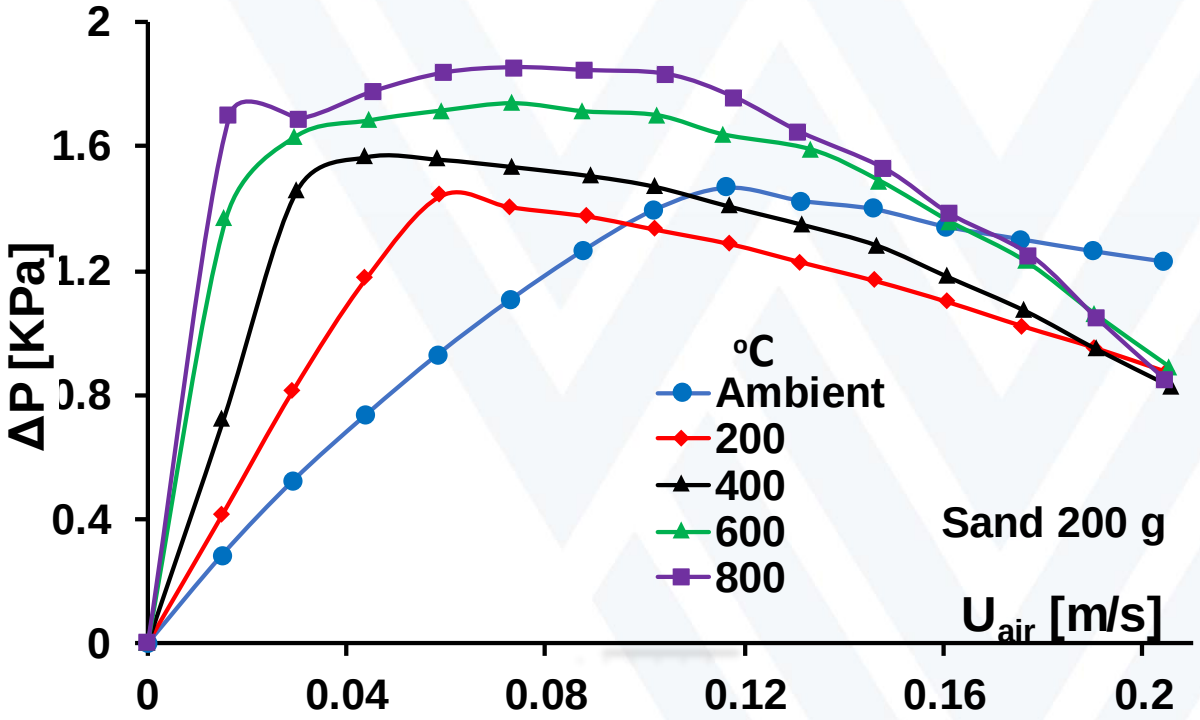


Results: Effect of temperature on ΔP across the distributor plate

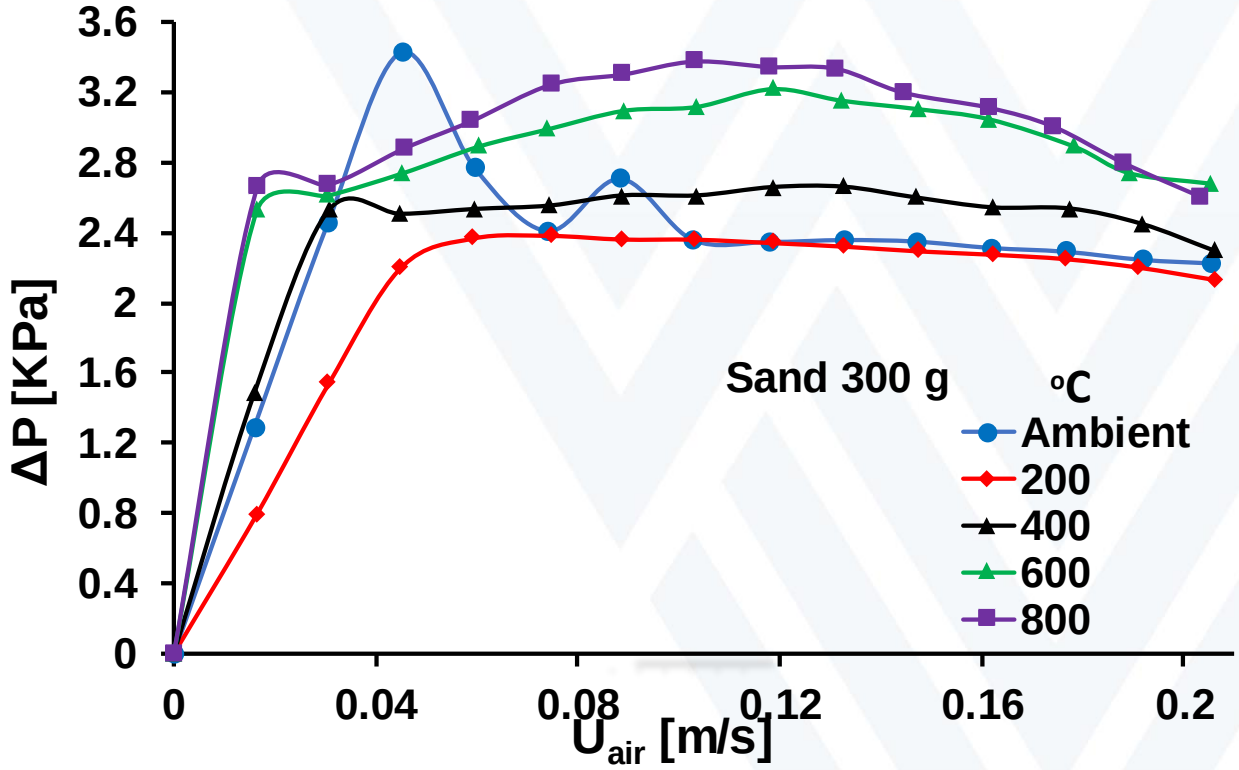


- Operating temperature affects the pressure drop across the distributor plate
- Temperature will affect bubbling characteristics

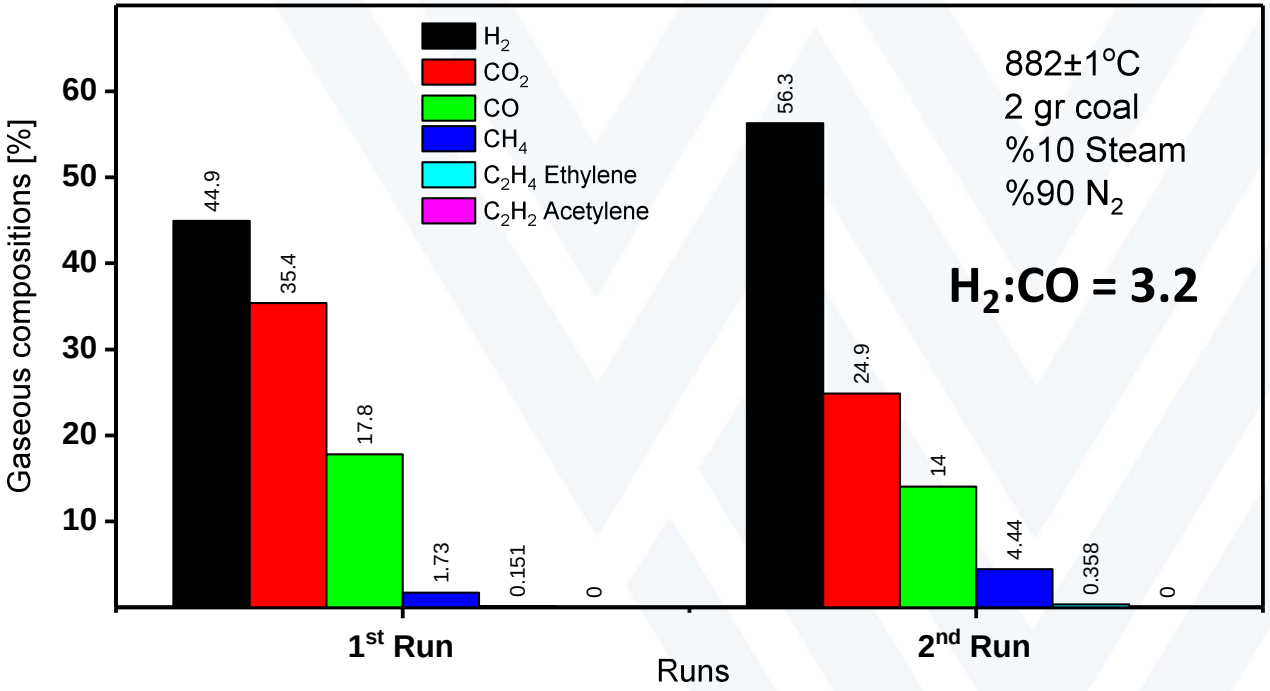
Results: Pressure drop across the bed – hot gasifier



Results: Pressure drop across the bed – hot gasifier



Coal steam gasification – Product composition



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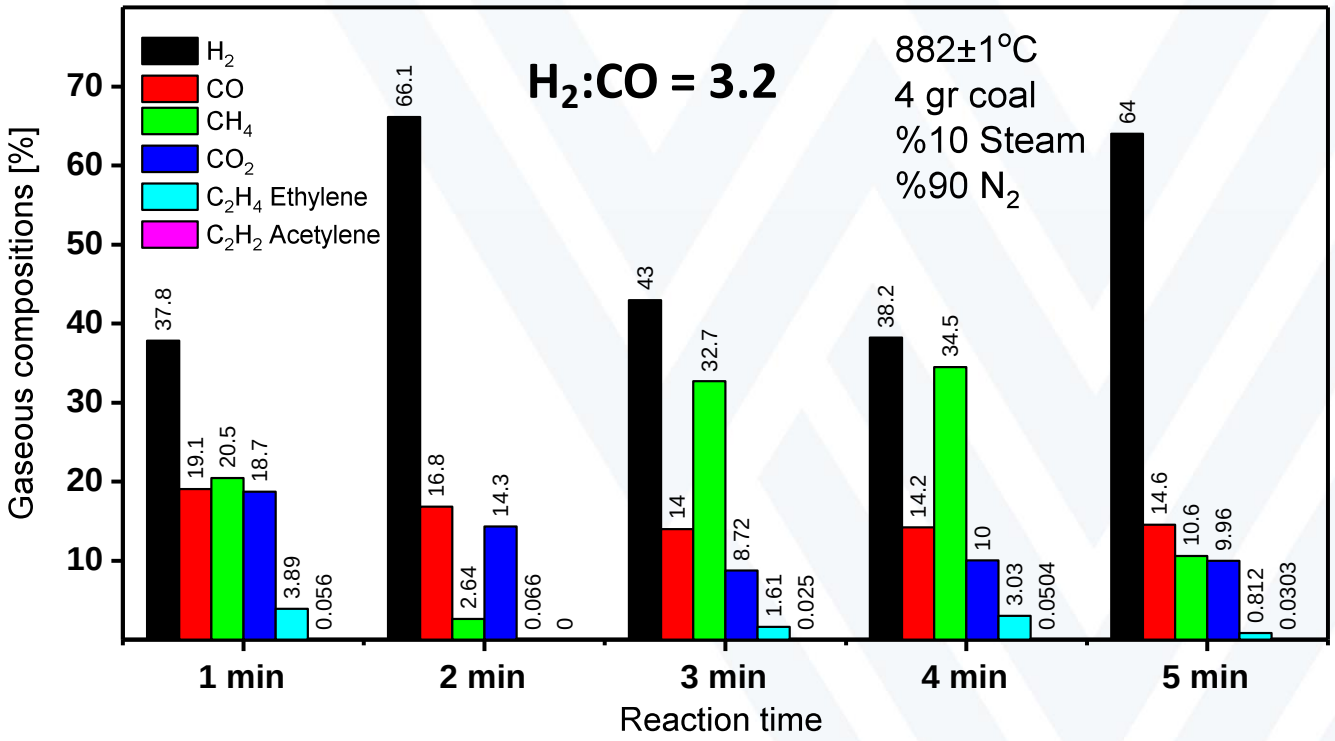
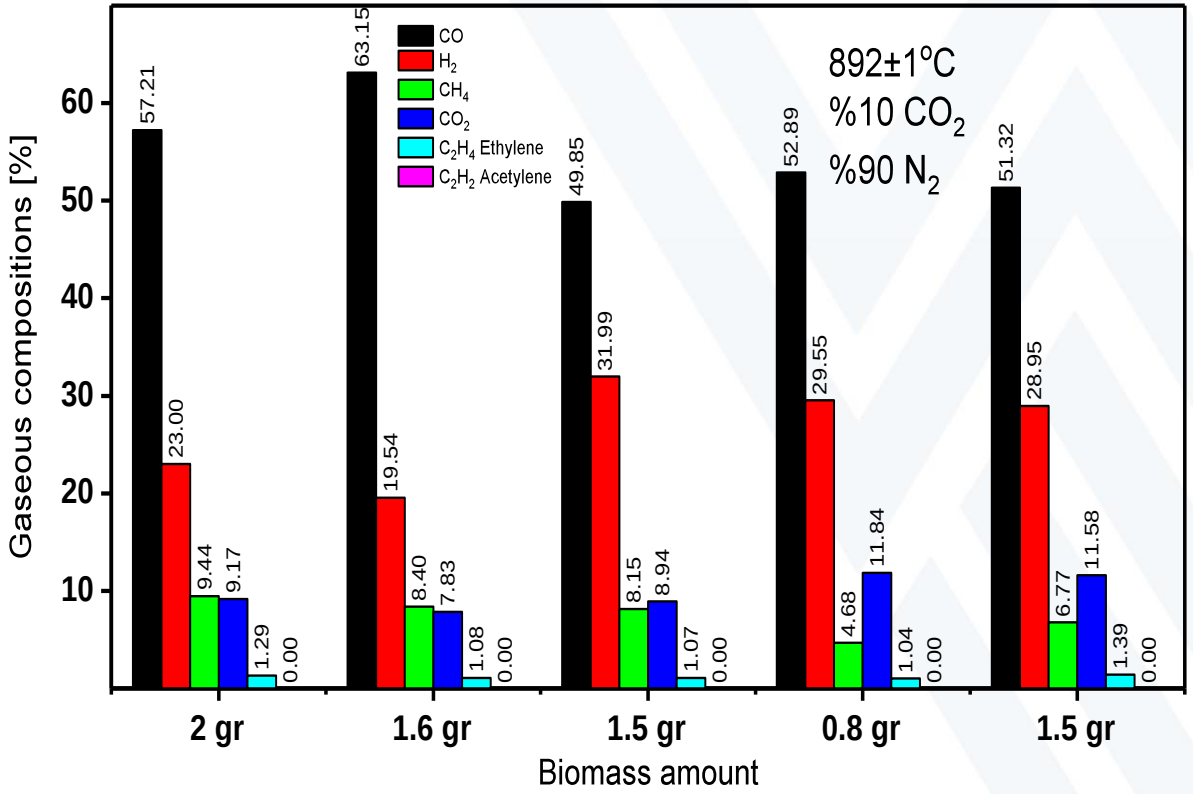


Biomass gasification – product composition



H_2:CO = 0.5

- Reverse water gas shift reaction affects product composition

Conclusions

- Binary mixtures with lower voidage ratio and higher bulk densities improve fluidization
- Operating temperature also effects the pressure drop through the distributor plate
- Preliminary results of coal and coal gasification are promising

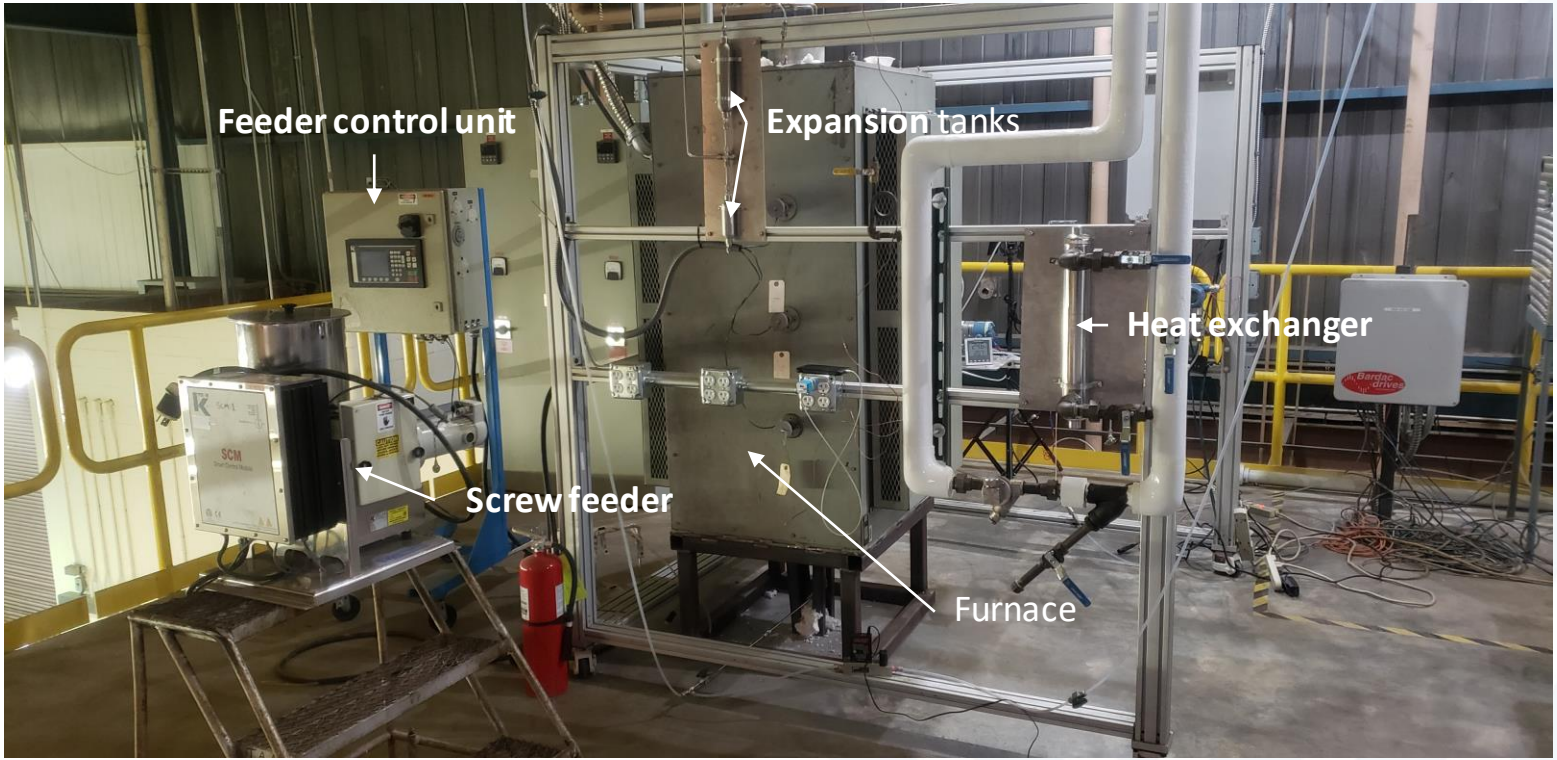
Future work

- Improve the feeding system (continuous)
- Improve the product gas sampling (continuous)
- Improve measurement (multiple locations)
- Improve temperature control

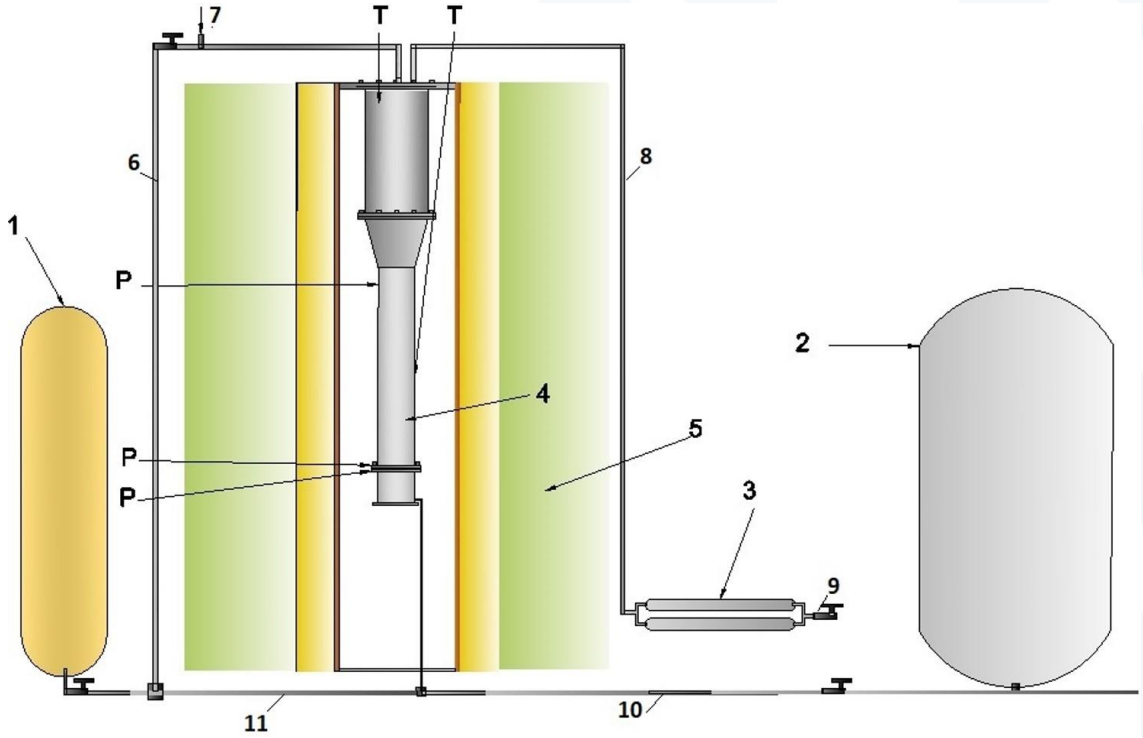
Acknowledgements

Thank you

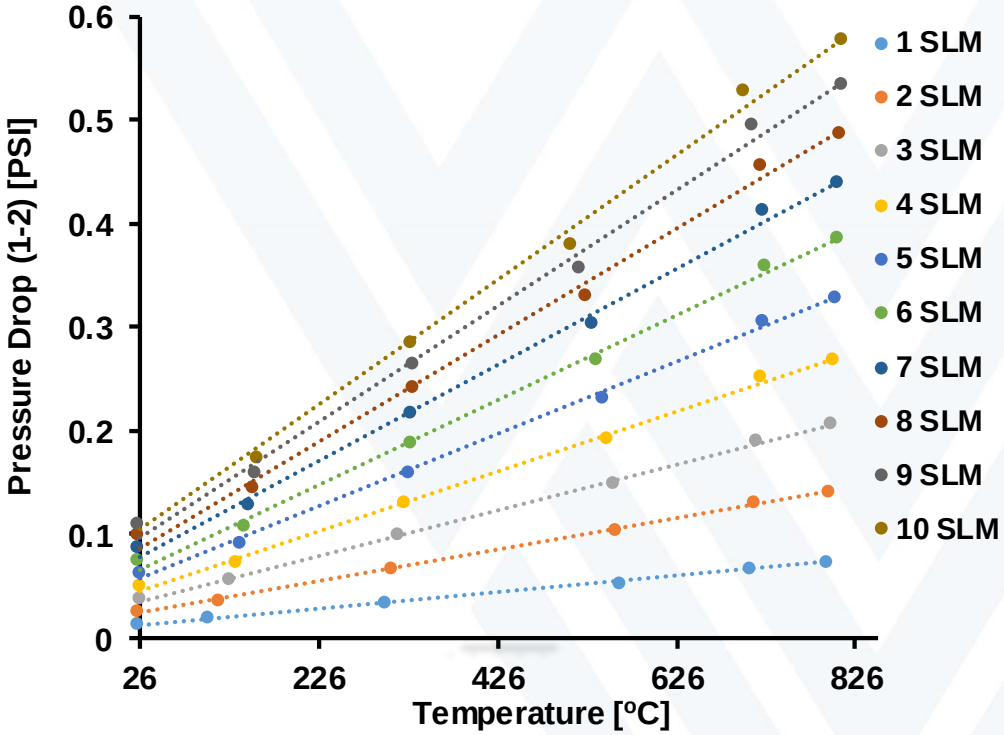
BFBG experimental setup



BFBG experimental setup



Bubbling fluidized bed reactor system. **P:** Pressure sensor, **T:** Temperature sensor, **1:** Nitrogen tank, **2:** Compressed air tank, **3:** Expansion tanks, **4:** Bed reactor, **5:** Furnace, **6:** Feeding system gas flow line, **7:** Feeding point, **8:** Output gas line, **9:** Gas sampling valve, **10:** Bed reactor cooling gas line, **11:** Bed reactor fluidization gas line.


Pressure Drop (1-2) [PSI]
0.6
0.5
0.4
0.3
0.2
0.1
0
26
226
426
626
826
Temperature [°C]
1 SLM
2 SLM
3 SLM
4 SLM
5 SLM
6 SLM
7 SLM
8 SLM
9 SLM
10 SLM

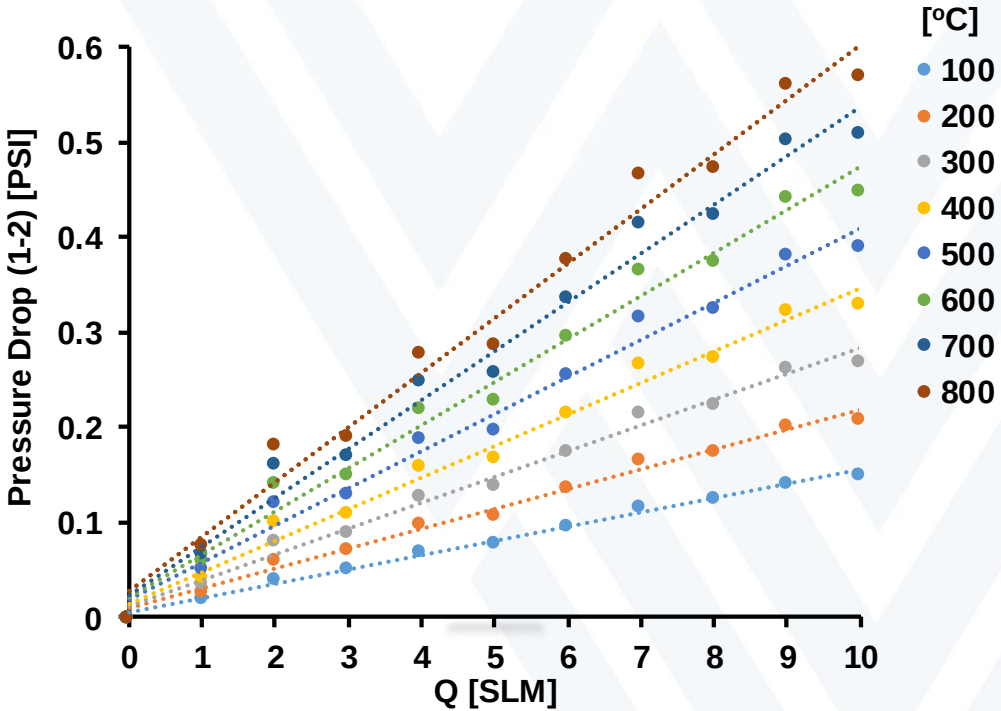

Pressure Drop (1-2) [PSI]
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
9
10
Q [SLM]
[°C]
100
200
300
400
500
600
700
800

Table 2. Material elemental analysis

Material	Moisture, (%)	Volatile, (%)	Ash, (%)	Nitrogen, (%)	Carbon, (%)	Hydrogen, (%)	Oxygen, (%)
Biomass (Hardwood)	7.16	75.65	0.32	0.9	45.25	4.65	49.2
Coal (Pittsburgh #8)	1.3	34	10.6	1.6	85.6	5.8	7

Objectives

- Design, build and operate a laboratory-scale bubbling fluidized bed gasifier (BFBG) using biomass (hardwood) and coal as feedstocks.
- Analyze the fluidization hydrodynamics of binary mixtures with biomass and coal as feedstocks by using a laboratory-scale BFBG cold-flow rig (CFR).
- Analyze the effect of temperature on fluidization hydrodynamics at actual experimental conditions up to 800 ^{o}C.
- Perform biomass and coal gasification operations in accordance with the data obtained from cold flow experiments and analyze the product gas compositions.
- Provide high quality data for NETL Multiphase Flow Group for modeling.

BFBG fluidization hydrodynamics analysis

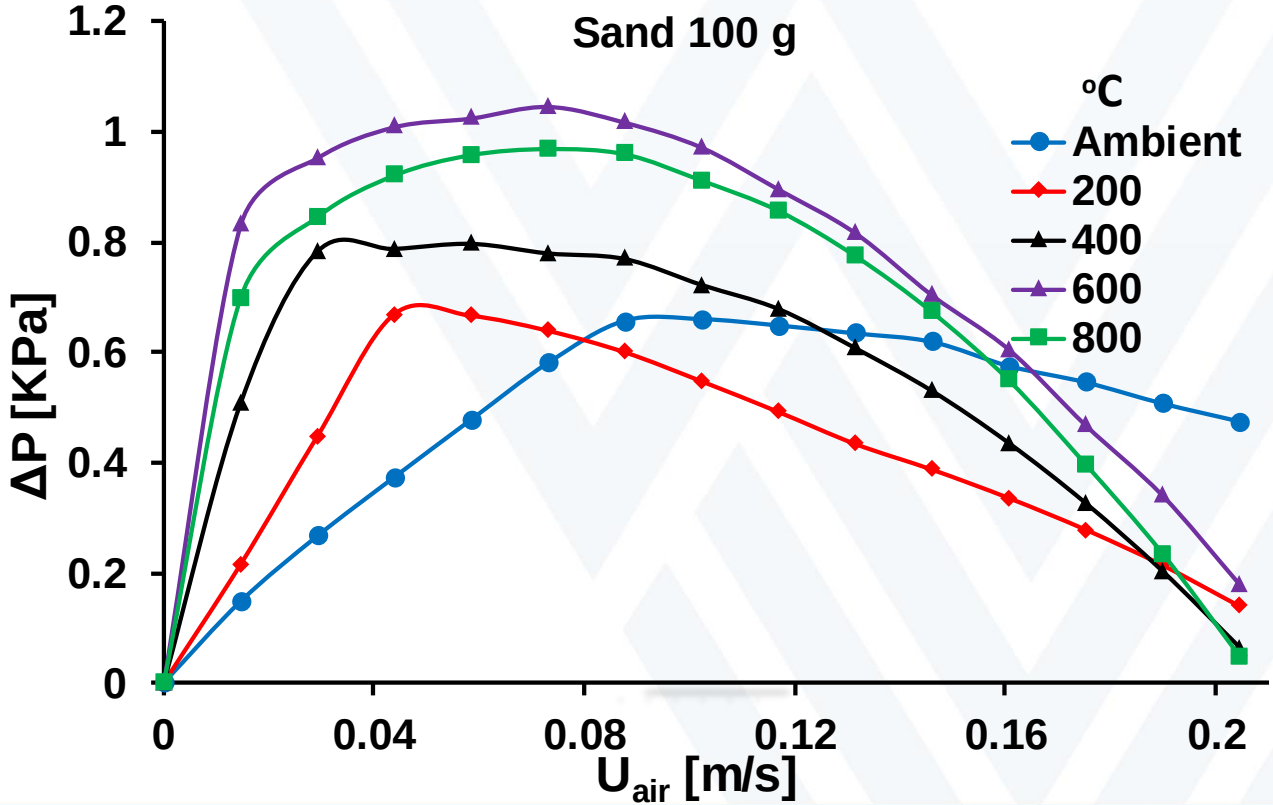


Table 2. Material bulk density and voidage analysis

Material (Mixtures)	Bulk density (g/cc)	Voidage (%)
Glass beads + coal	1.61	35
Glass beads + hardwood	1.43	38
Sand + coal	1.56	41
Sand + hardwood	1.38	44