A GAS-SOLID VORTEX REACTOR FOR THE FAST PYROLYSIS OF BIOMASS

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Introduction

Fast pyrolysis is one of key potential technologies for the production of chemicals, fuels and energy from biomass.

- Bio-oil is produced at high yields (~70 wt. %), is suitable for decentralized production, is practical for handling and transportation.
- The REACTOR is crucial for the success of the technology.
- None of the current reactor concepts fully satisfies the main requirements of the fast pyrolysis process.

 fluidized beds, rotating cone, auger and ablative reactors are currently being used. The Gas-Solid Vortex Reactor (GSVR) is a novel reactor technology which can benefit the fast pyrolysis process in terms of yields and bio-oil quality.

Demonstration Unit

Proof of concept → First reactive GSVR
Designed for basic research purposes
Biomass flow rate 0.14-1.1 g s⁻¹
High-value chemicals and transportation fuels from biomass

When compared with Circulating and Static Fluidized Beds (SFB and CFB) the GSVR:

- Minimizes intra-particle heat transfer constrains
- Shifts the operation towards non-isothermal kinetic control
- Reduces pyrolysis times by approximately 50%

GSVR Design

Replacing gravity by centrifugal force
- The centrifugal field can be generated either by rotating the chamber or by injecting gas tangentially into a static chamber. The latter is the operation mode of the GSVR.

Main advantages over conventional Fluidized Bed Reactors
- Gas-solid slip velocities 3-5 times higher
- Improved bed uniformity
- Higher interfacial heat transfer
- Enhanced temperature control
- Rapid removal of pyrolysis vapors (~10 ms)

GSVR schematics

- Eight tangential inlet slots, 1 mm width
- Positioned at 10° with respect to the tangent
- Gas inlet velocity of 60-140 m s⁻¹
- Diverging side wall shape
- Profiled bottom
- Reduced gas backflow
- High speed (3-5 rps) 10 mm screw for biomass injection
- Positioned at 18° inclination with respect to the horizontal plane
- Jacketed for cooling

Gas-only CFD Simulations

Parameters for the Computational Fluid Dynamics (CFD) simulations
- Nitrogen mass flow: 6.7 g s⁻¹
- Inlet temperature: 842 K
- Turbulence: Reynolds stress Model
- Compressible flow
- 2.8 million cells mesh
- 3rd order discretization

- Rotating flow in the outer annulus induced by the gas at the main inlet
- Uniform gas velocity at the slots inlet
- High axial velocity next to the shaped wall
- Axial velocity decreases due to the larger cross-sectional area

Conclusions

The GSVR enables fluidization in a centrifugal field with particle inertial forces that exceed the gravitational force.

- A uniform bed of particles with bed-width-to-height ratios and gas-solid slip velocities much higher than in conventional fluidized beds can be sustained.
- Larger gas-solid slip velocities lead to intensification of interfacial transfer of mass, energy and momentum.

The GSVR allows for improved control of the pyrolysis temperature reduced gas-solid space time ratio.

Bio-oils with a higher selectivity towards targeted components such as bio-aromatics can be produced.

Future Work

- GSVR assembly and cold flow tests
- Pyrolysis experiments with various biomass types
- Detailed characterization of the bio-oil
- Optimization of the unit: GSVR operation conditions, solids feeding and bio-oil condensation
- Particulate flow CFD simulations

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