



Novel design of multiphase reactors for Biomass-To-Liquid synthesis

**Ahmed Youssef, Milorad Duduković, and Muthanna
Al-Dahhan**

Washington University in St. Louis

**BioEnergy II
Rio de Janeiro, Brazil**

11/3/2009

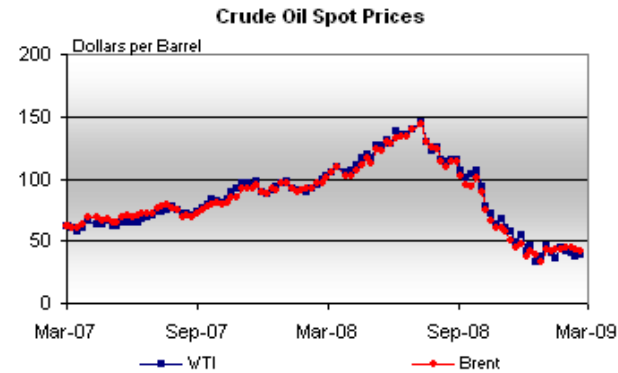


Outline

- Introduction
- Bubble Column Reactors – an overview
- Objective: Scale-up of Bubble Columns
- Novel design and methodology assessment
- Sample results

Energy concerns and bubble columns

- Fluctuating oil prices renew the interest in finding alternatives.



Crude oil spot prices (Source: EIA)

- Generation of liquid fuels from Biomass via the Fischer-Tropsch synthesis is amongst the considered processes.



- Bubble column reactors are considered the reactor of choice for the conversion of syngas to liquid fuels.

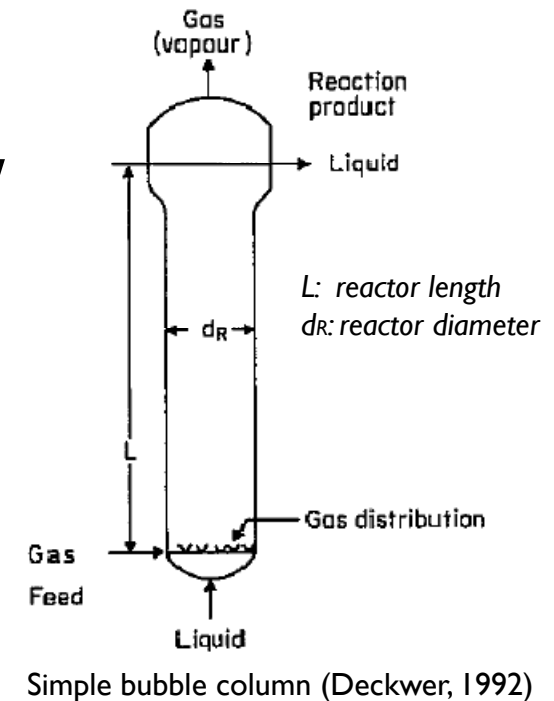


Fischer-Tropsch and the Environment

- The FT process is environmentally friendly and assures sustainability.
- Fuels and chemicals produced by the FT synthesis are of high quality because (van derLaan and Beenackers, 1996):
 - They have low aromaticity,
 - They have zero sulfur content,
 - They exhibit superior combustion properties, and
 - They produce reduced emissions to the atmosphere.
- The new and stringent regulations may promote replacement or blending of the conventional crude oil-based fuels by clean FT products.

What is a bubble column?

- Bubble columns are cylindrical vessels wherein gas is sparged, via a distributor, in the form of bubbles, into liquid or liquid-solid suspension (Slurry bubble columns).
- They are used for processes involving oxidation, polymerization, wastewater treatment and Fischer-Tropsch (FT).



Advantages	Disadvantages
Good heat transfer	Significant phase back-mixing and Difficult to scale-up and design due to complex interaction among phases.
Ease of construction and operation	
Absence of moving parts	
Low maintenance costs	
Good mass transfer	



Scale-up of bubble columns


- The hydrodynamics of bubble columns are strongly affected by the scale of operation.
- Scaling rules via geometrical and dynamic similarities are hard to achieve in such complex systems.
- Novel approaches are needed to solve the scale-up quest.

Objective: To enhance the state-of-the-art of scale-up of bubble column reactors.

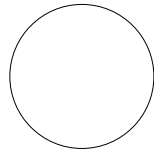
SCALE-UP: PROBLEM DEFINITION

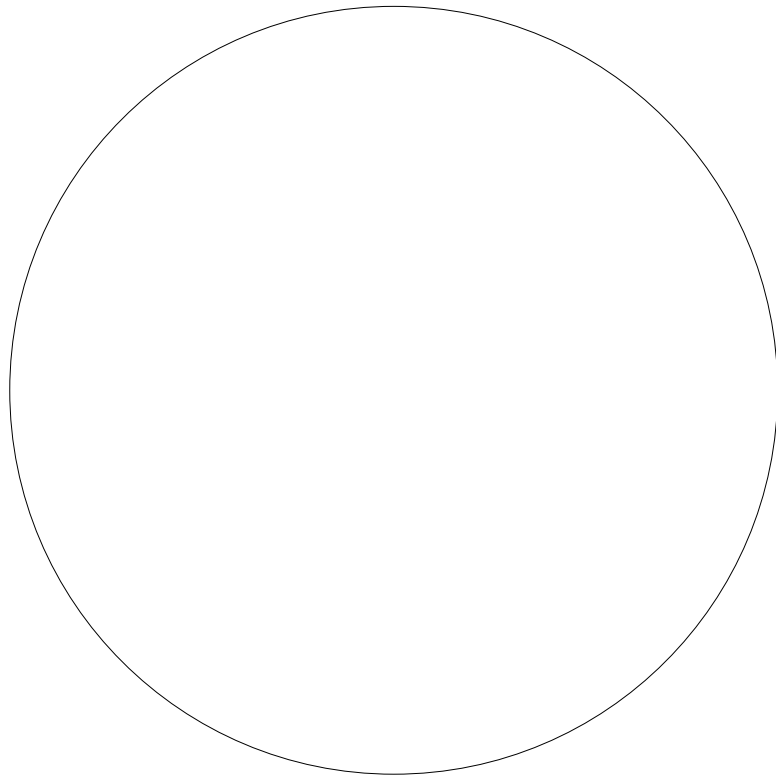


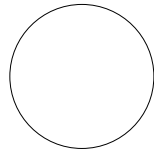
Source: www.sasol.com

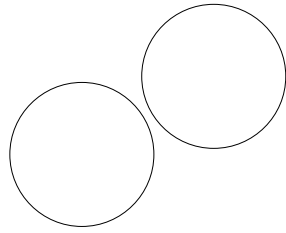


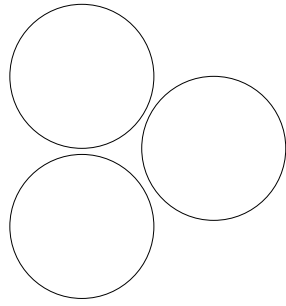
**Why scale-up?
Why not scale-in-parallel?**

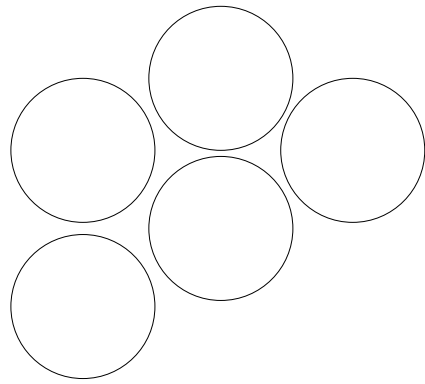


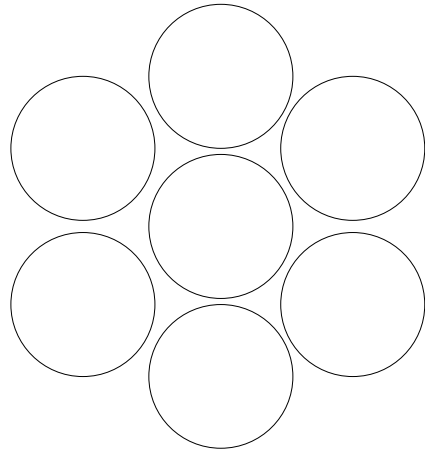


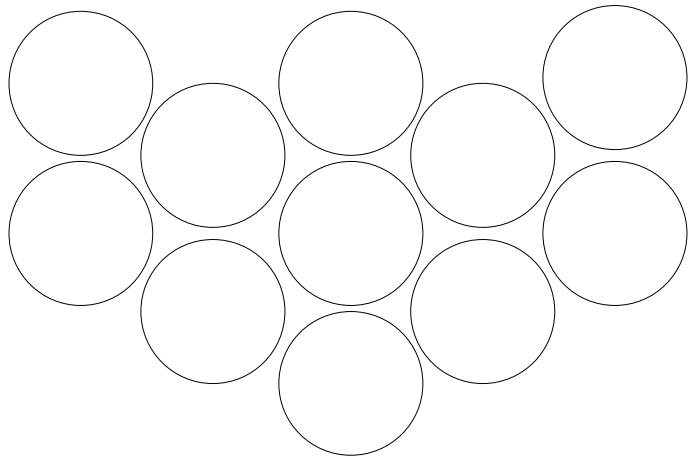


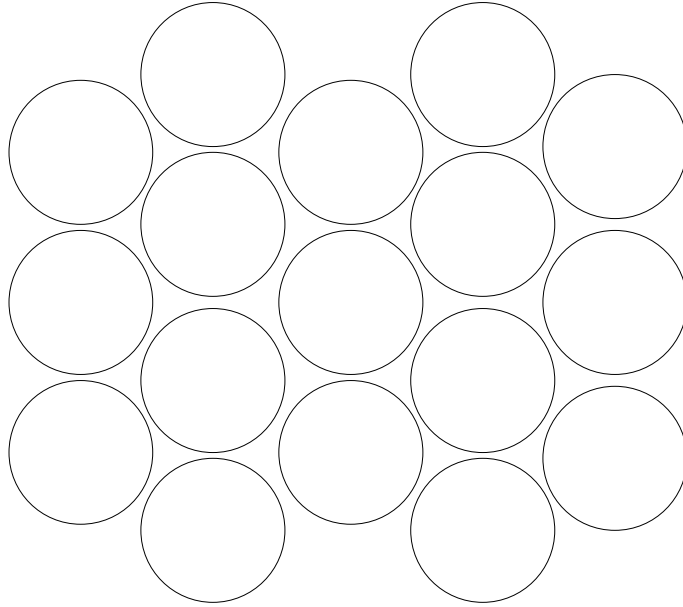


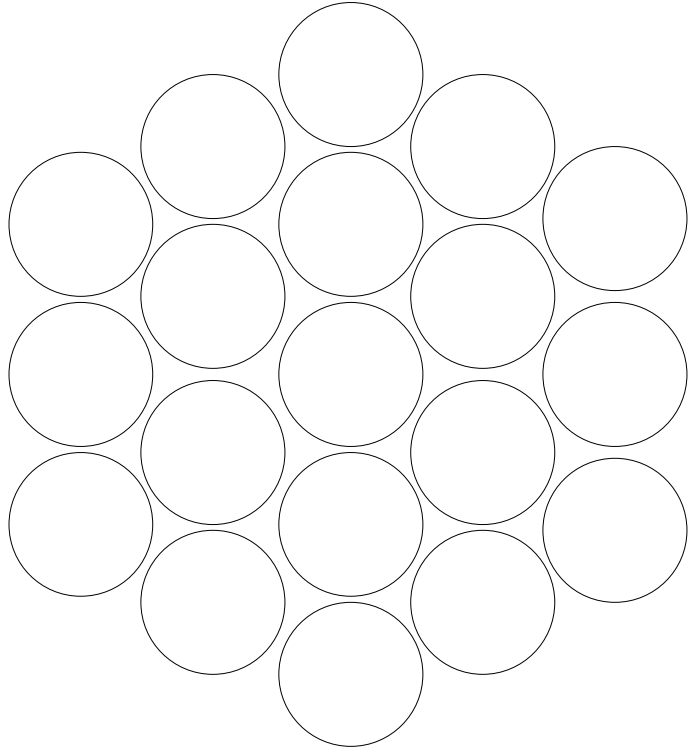


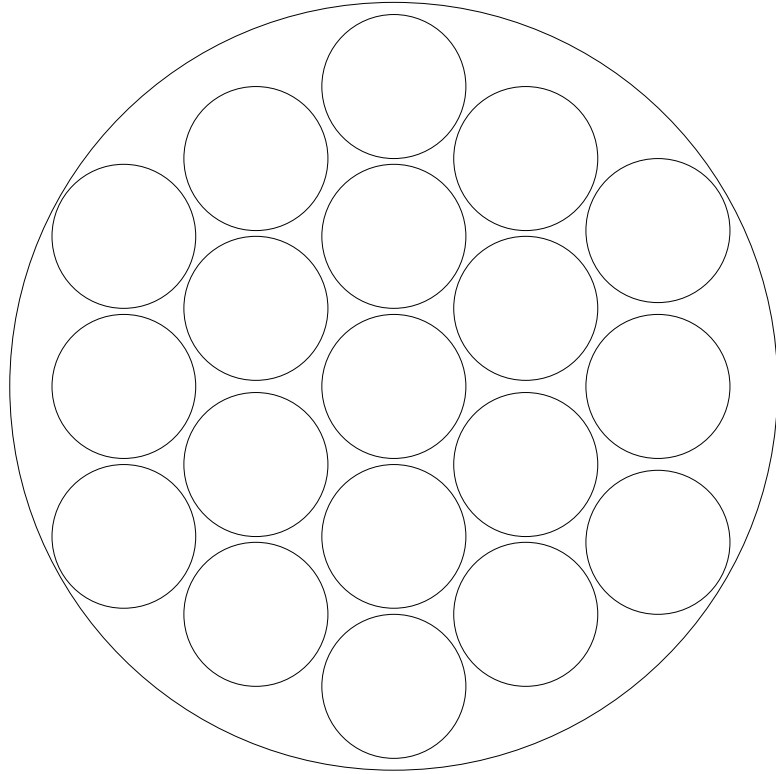


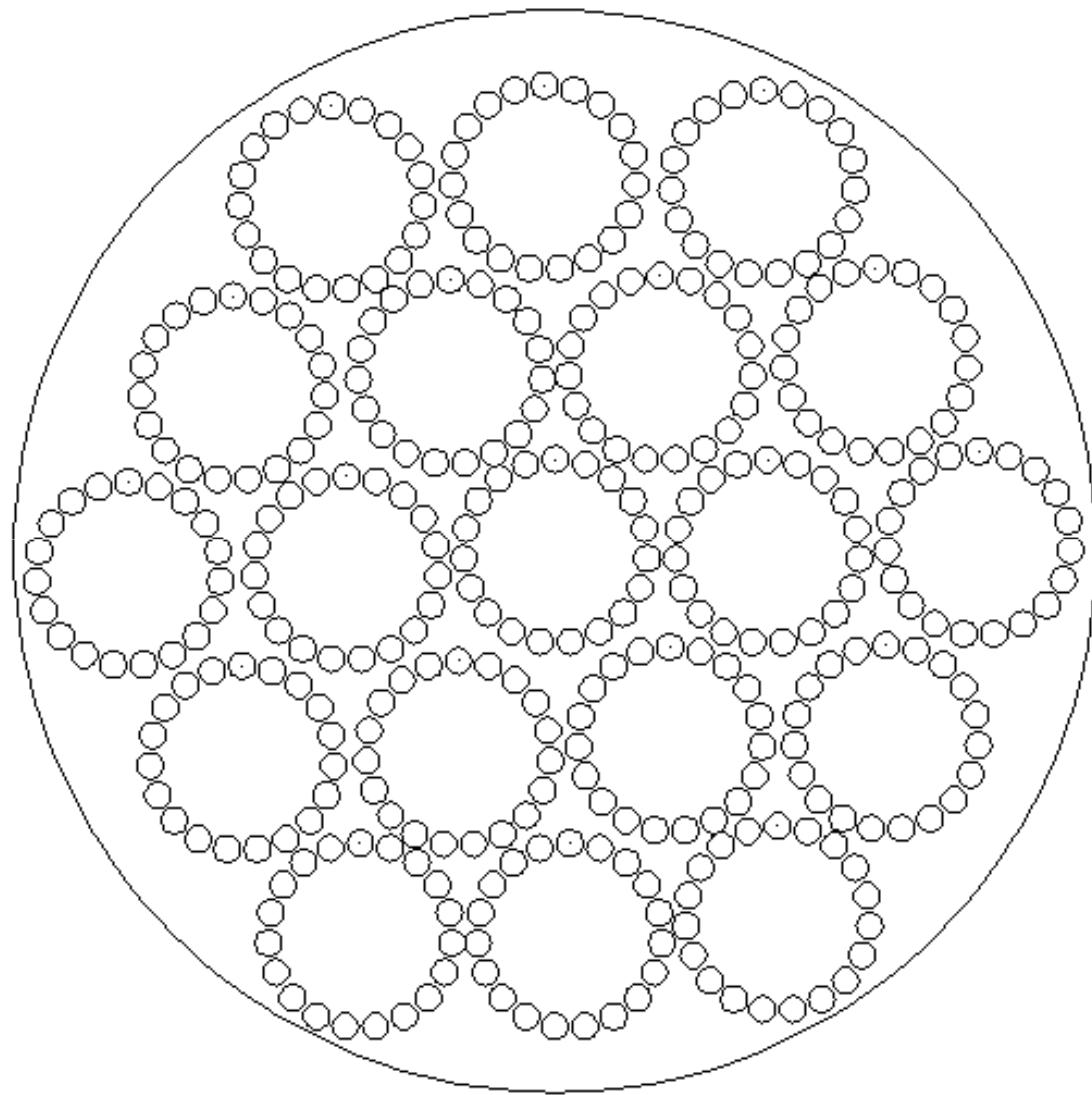










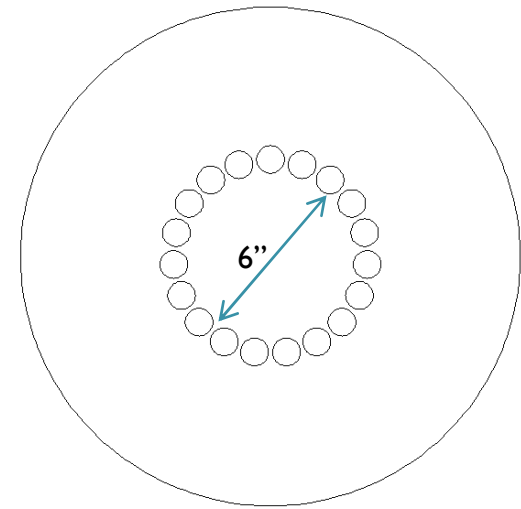


Scale-up methodology

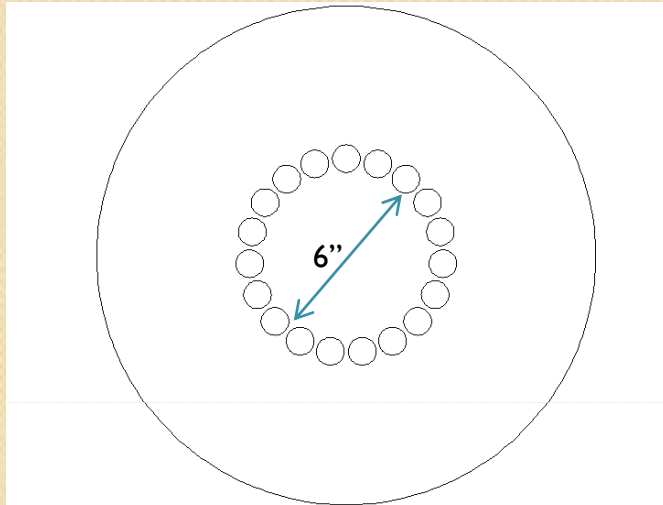
- **Reactor compartmentalization approach**
 - ❖ Can vertical internals be arranged to form small internal bubble columns within the large reactor wall?
 - ❖ Can vertical internals, in such an arrangement, mimic the behavior of columns of the same smaller diameter having a solid wall instead?
- **A scale-up methodology is proposed based on controlling the effect of scale using internals by means of reactor compartmentalization**

Steps:

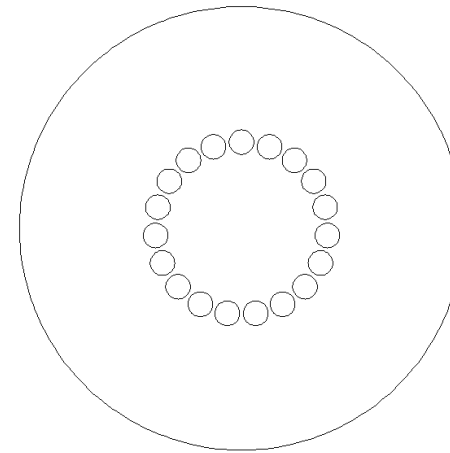
- The large reactor diameter is subdivided into similar, vertical compartments by means of the cooling tubes.
- The compartments are to have a diameter similar to that of a small scale column on which investigations can be performed.
- The various hydrodynamic parameters within each compartment are to be compared with those measured in a bubble column of the same diameter.



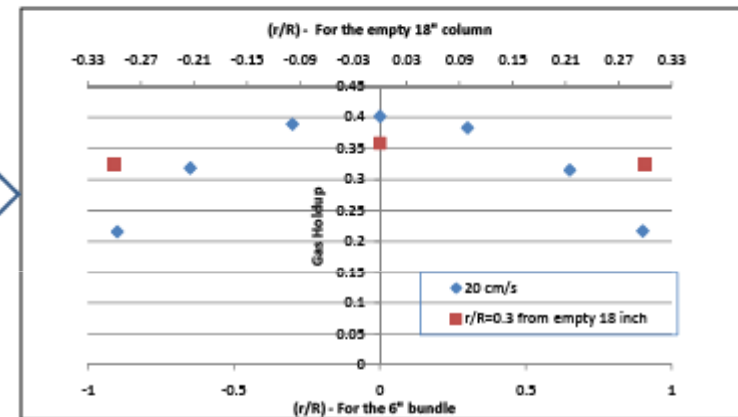
Internal single tubes bundle



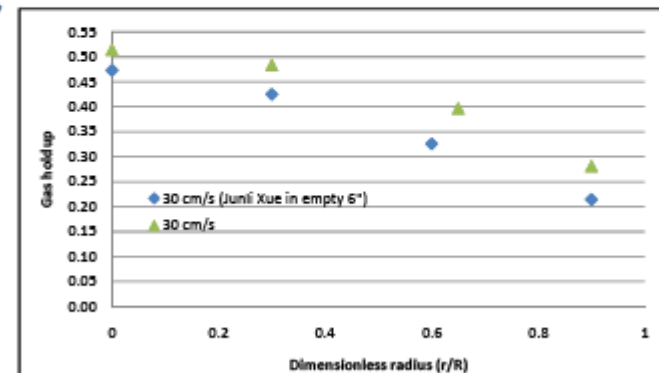
Preliminary Results



The tubes showed an effect close to that of a solid wall (low local ϵ_g value) when comparing gas holdup values at $r/R = 0.9$ inside the circular tube bundle with the equivalent dimensionless radius in the empty column.



A close agreement between resulting gas holdup profile inside the single tube bundle and the data in 6" bubble column is observed.



Questions?

