University of Warwick, School of Engineering,
Coventry, CV4 7AL, England

Circulating Fluidised Bed: Standpipe And L-valve Operation

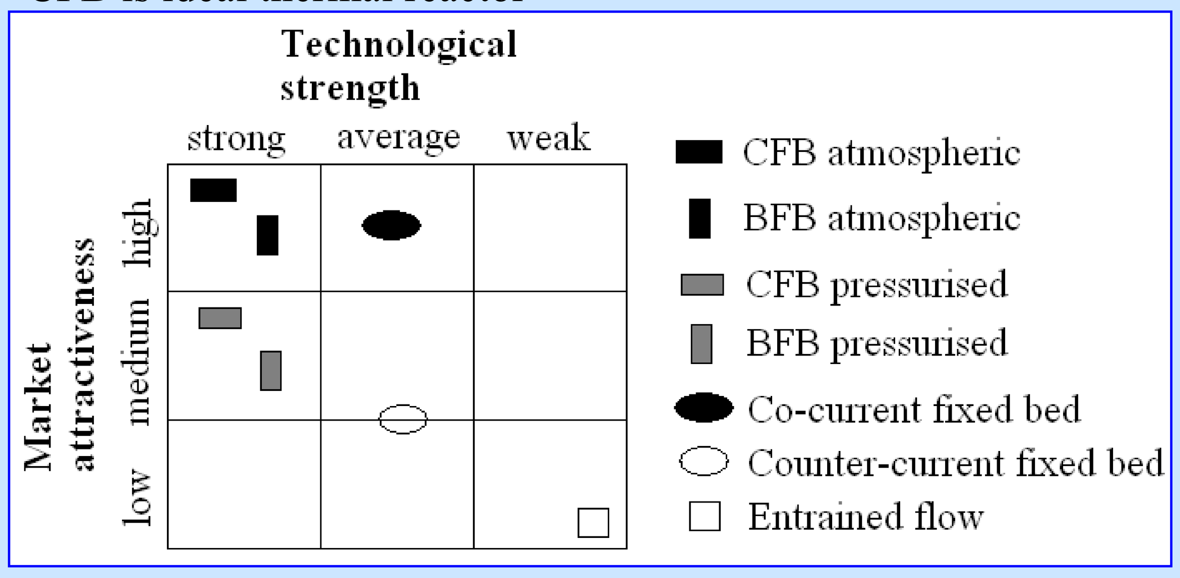
Chian Wen Chan,
Jonathan Seville, Jan Baeyens

THE UNIVERSITY OF WARWICK

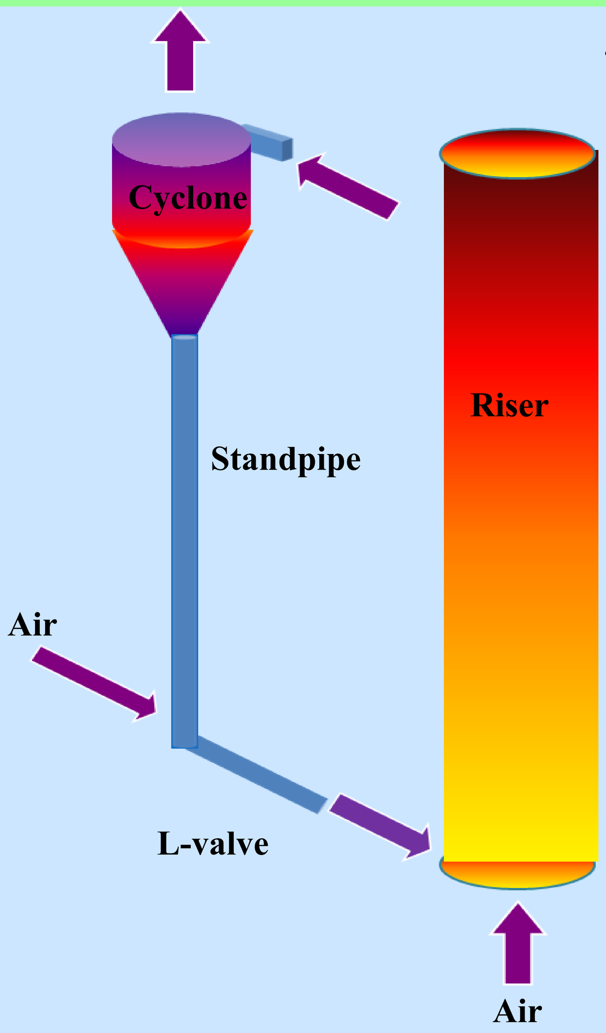
OVERVIEW

Research Background

- CFB is increasingly used in combustion, pyrolysis, gasification of biomass
- CFB is ideal thermal reactor



Circulating Fluidised Bed (CFB)



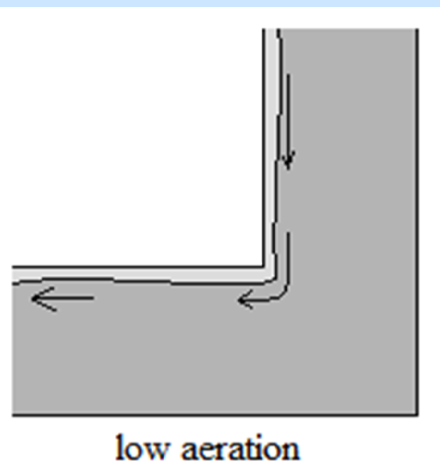
- CFB
  - riser, cyclone, standpipe and L- valve
  - given velocity and solids circulation
  - solids circulation is function of standpipe and L-valve design and operation

Standpipe

- Acts as a temporary solids reservoir
- Stabilises CFB operation.
- Characterised as fluidised and non-fluidised flow (moving packed bed)
- Solids flow not uniform over its cross-sectional area (Chian et al., 2009-a).

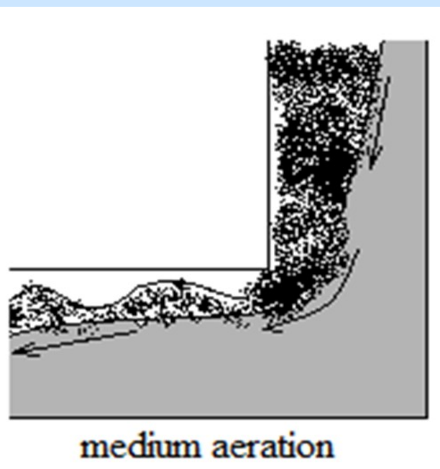
L-valve

- A non-mechanical valve
- Operable at high temperature and high pressure
- Able to handle corrosive gases and abrasive particles.
- Reduced risk of wear and seizure.
- Low in cost (easy to maintain).
- Solids flow = function (injection gas into the L-valve in excess of the minimum fluidisation velocity, U_{mf}).



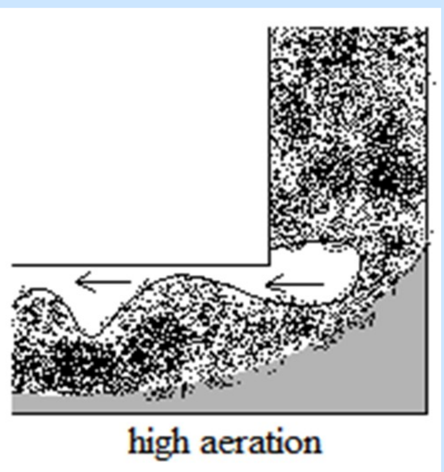
At low aeration (U<Umf):

- A narrow fast-moving stream of solids at the top.
- Size of channel flow increases with increasing particle size.



At medium aeration:

- Dunes cause pressure and solid discharge fluctuation.
- Frequency of dunes ~ 4Hz.
- Dunes at the top at medium solids flows.



At high aeration:

- Frequency of dunes ~ 1Hz.
- Highly unstable and hindered, due to the concurrent formation of large dunes and cavities.

Experiments: PEPT (positron emission particle tracking)

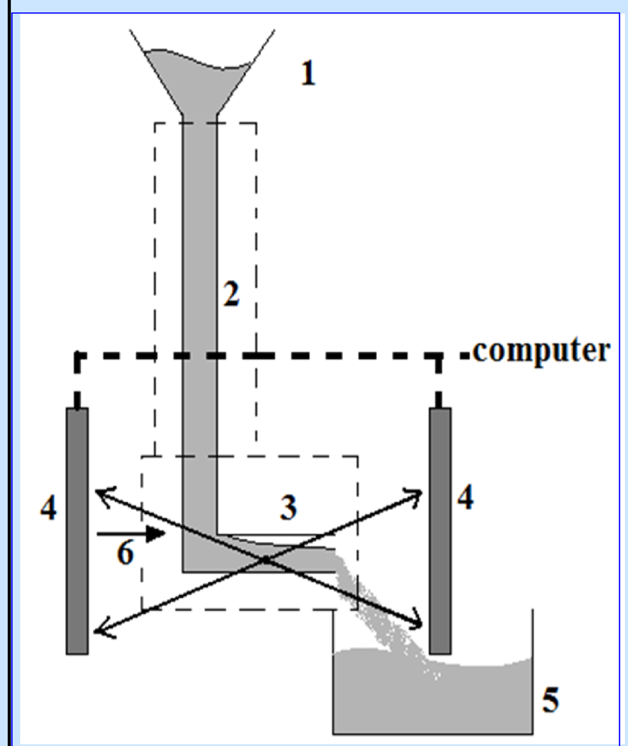
PEPT

- Involves introducing a radioactive tracer which is of similar mean size (diameter, d_p of 100 µm) to that of the bed material.
- Bed consisting of sand of density, ρ_p of 2260 kg m^{-3}.
- Motion of the radioactive tracer captured of gamma sensitive cameras.
- An extensive list of consecutive particle locations (~1 position in X, Y and Z coordinates every 4 ms) is obtained.
- Average velocity vector and occupancy plot may be constructed.

Set-ups

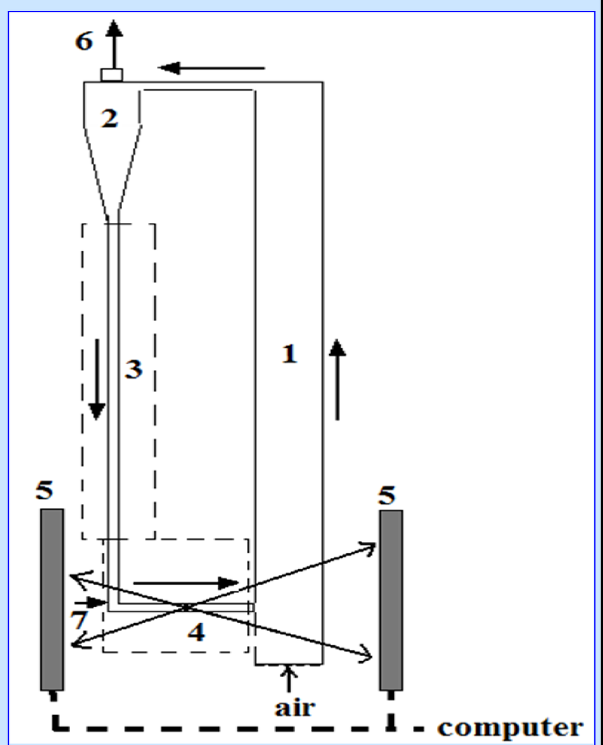
- Types
  - **L-valve free discharge**
  - **L-valve discharge with back pressure/riser.**
- Injection air velocity into the L-valve varied between 1-20 U/U_{mf}.
- Set-up for free discharge also used to study standpipe flow.

Free discharge



Setup of the L-valve free discharge: hopper (1), standpipe (2), L-valve (3), γ-ray detectors (4), weighing bin (5) and compressed air injection (6)

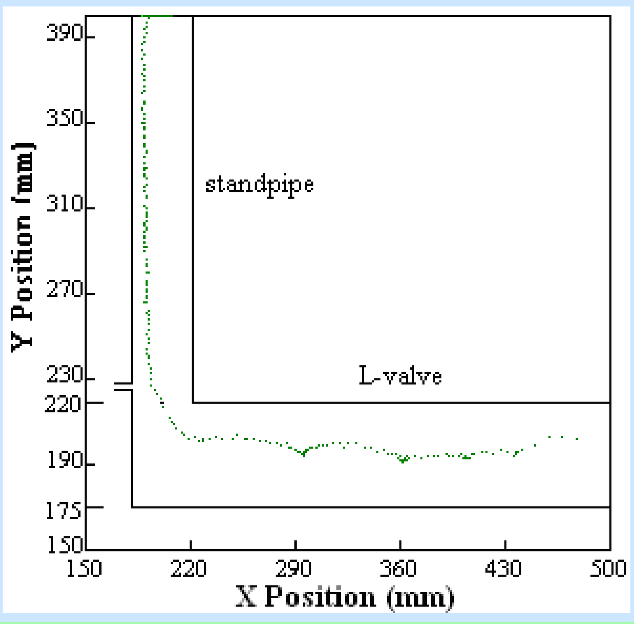
Riser discharge



Setup of the L-valve (CFB): riser (1), cyclone (2), standpipe (3), L-valve (4), γ-ray detectors (5), air exhaust (6) and compressed air injection (7)

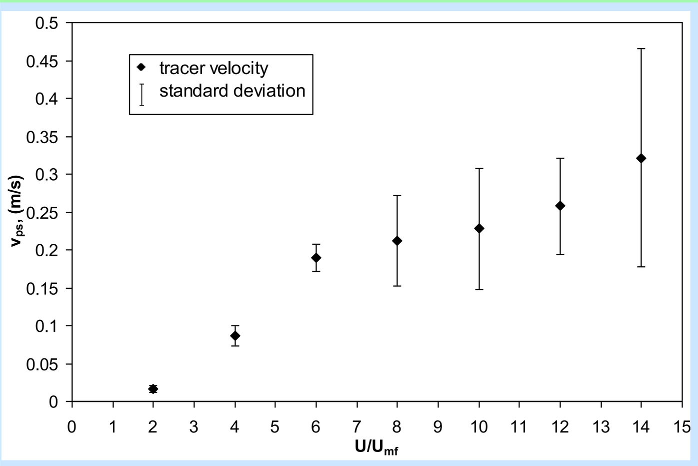
RESULTS AND DISCUSSIONS

Observations of standpipe and L-valve



PEPT trajectory of tracer. Standpipe and L-valve, each with 45 mm I.D.

Standpipe

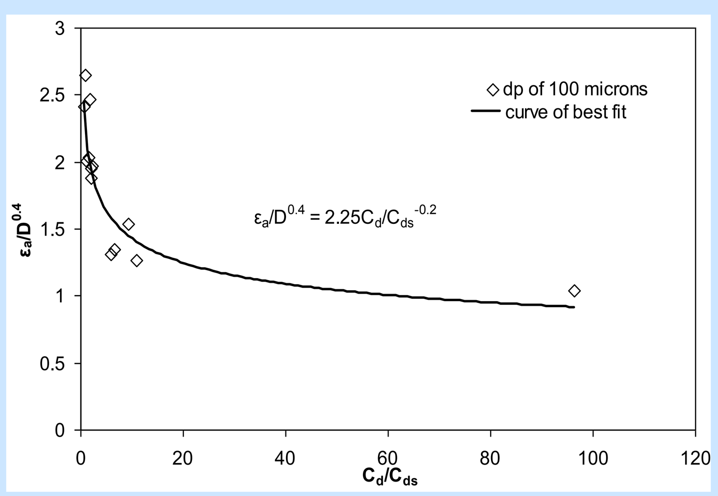


Average v_{ps} at standpipe ID = 2.5cm

- L-valve flow stable up to U/U_{mf} = 6.
- At U/U_{mf} < 6, increasing fluctuations of v_{ps}.

At increasing U/U_{mf}:

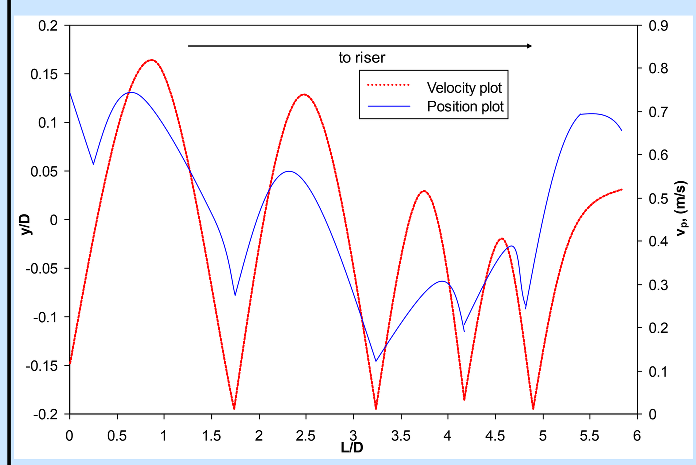
- Downward velocity of tracer (v_{ps}) increases
- Solids vertical acceleration starts higher up the standpipe.



- Development of equation for drag coefficient in standpipe flow
- $$\frac{\varepsilon_a}{D^{0.4}} = 2.25\left(\frac{C_d}{C_{ds}}\right)^{-0.2}$$
- with voidage in standpipe (ε_a), drag coefficient of gas flow (C_d), drag coefficient of a particle (C_{ds}), diameter of standpipe (D)

- Drag force is proportional to C_d
- Drag force is upwards
  - **If weight of particle > drag force, downward motion and acceleration**
  - **If weight of particle < drag force, upward motion.**
- Reducing D reduces drag force, provides more stable flow

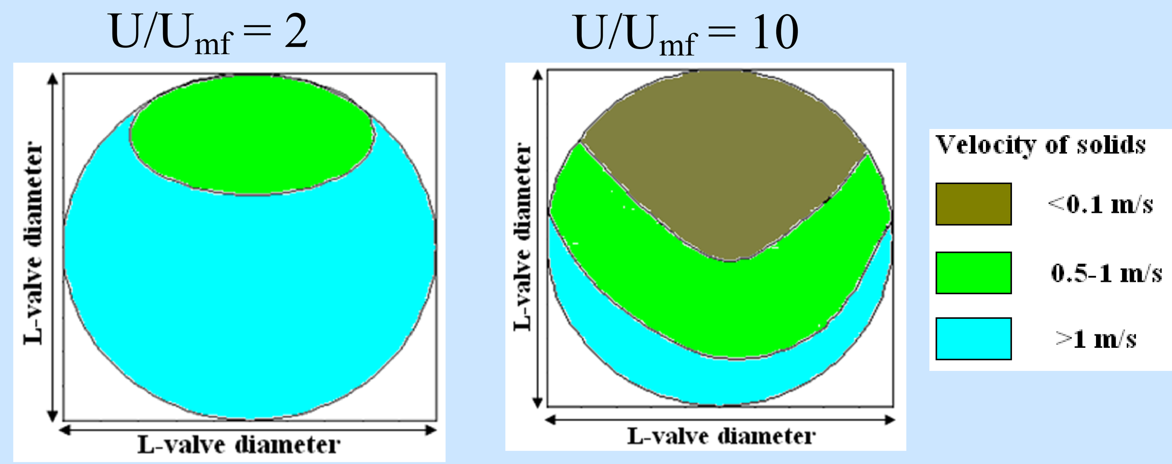
L-valve

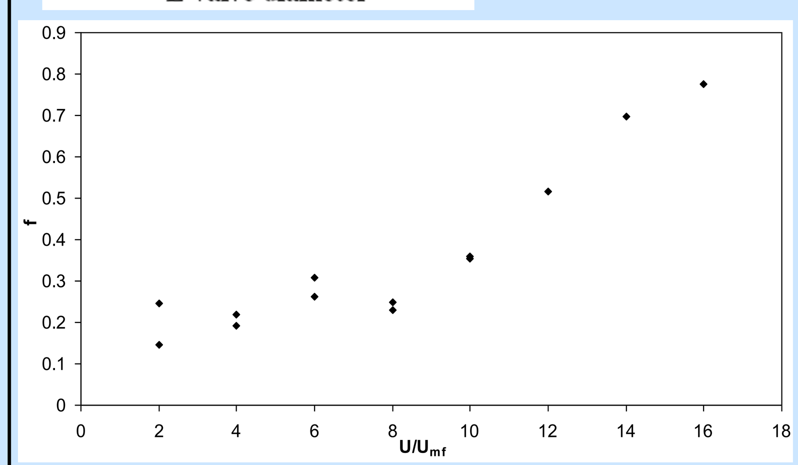


- 5 complete dunes.
- velocity of tracer particle (v_p) = function (position of solids with respect to dunes)
- peaks at the nodes.
- slows down at the troughs .

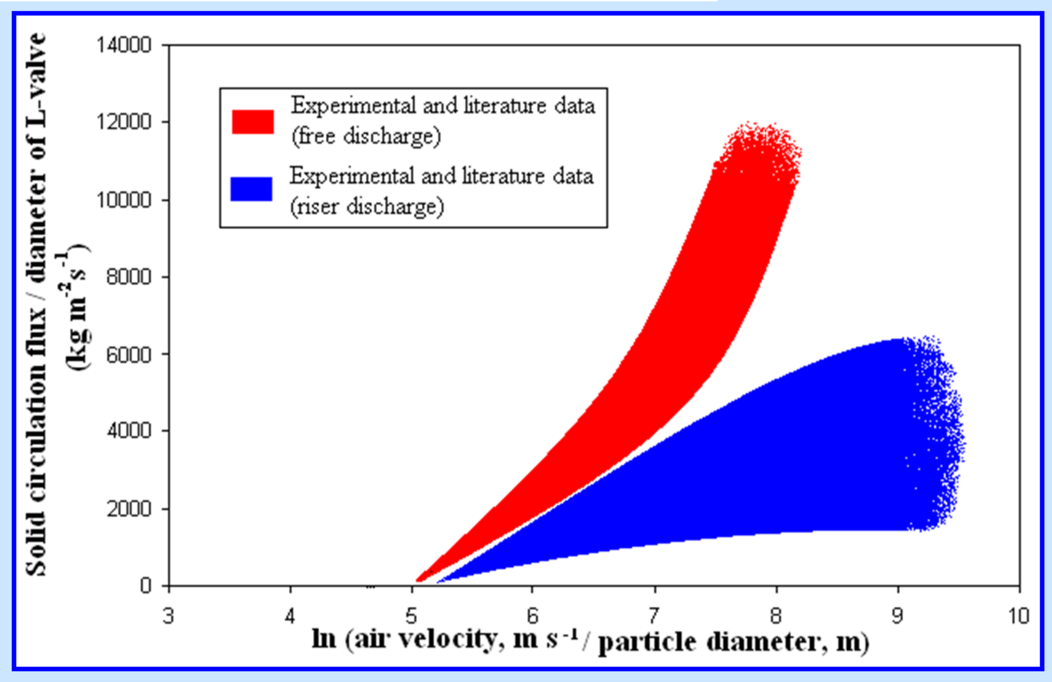
Magnitude of zones = function of (z/D, L/D and U/U_{mf})
- Zone I, stagnant or very slow
- Zone II, moderately slow moving
- Zone III, fast moving region of solids

Cross-sectional view at constant L/D of 2.5





- f = A_o/A, fraction (A_o) of cross-sectional area (A)
- f = function (U/U_{mf})



- Chian et al., (2009-b) compared data with riser discharge and free results by researchers.
- L-valve free discharge exceeds riser discharge
- Correlations for free discharge not to be applied on riser discharge

CONCLUSION

- Advisable to operate in stable mode i.e. at L-valve aeration , $U/U_{mf} \leq 6$
- L-valve discharge rate is limited by maximum permissible hopper/standpipe flow
- Standpipe design should be adjusted to L-valve design
- At same U/U_{mf} : free L-valve discharge >> L-valve discharge in riser

REFERENCES

- Bridgwater, A.V., Renewable fuel and chemicals by thermal processing of biomass, Chemical Engineering Journal 91, (2003), p. 87-102
- Chan, C.W., Seville, J.P.K., Fan, X. and Baeyens, J., Solid Particle Motion in Standpipe as Observed by Positron Emission Particle Tracking, Powder Technology, 194, (2009-a), p. 58-66
- Chan, C.W., Seville, J.P.K., Fan, X. and Baeyens, J., Particle Motion in L-valve as Observed by Positron Emission Particle Tracking, Powder Technology, 193, (2009-b), p. 137-149