TEST CASE 3: Circulating Fluidised Bed

Summary

This case concerns gas-solid flow in a **C**irculating **F**luidised **B**ed flow with sand. The CFB is 0.400m id and 15.6 m long. Two air flows 0.4524 kg/s and 0.6032 kg/s are examined with the solid mass flux 9 kg/s/m^2 and 17 kg/s/m^2, respectively. The experiments are carried out in ambient conditions.

Calculation Request

- Axial profile of pressure along the CFB
- Radial profiles of solid volume concentration and solid velocity at different heights

Information:

Prof. J. Werther and Prof. E-U. Hartge
Technical University of Hamburg-Harburg
Denickestr. 15
21071 Hamburg
Germany
e-mail : werther@tu-harburg.de
e-mail : hartge@tu-harburg.de
tel : 49–40-42878-3039/3239
fax : 49-40-42878-2678

Experimental Set up

The experiments were carried out in a circulating fluidised bed system with a cylindrical riser. Quartz sand with a surface mean diameter of $d_p \approx 140$ µm was used as bed material. The test case includes two different operating conditions:

Case A: Gas mass flow m=0,4524 kg/s, Solid mass flux Qs = 9kg/m^2/s

Case B: Gas mass flow m=0,6032 kg/s, Solid mass flux Qs = 17kg/m^2/s

The experiments were carried out with air at ambient temperature and pressure (20°C, 1bar). The CFB unit is shown in 1. It has a diameter of 0.4 m and a height of 15.6 m. The fluidising air is provided by a roots blower (Aerzener Maschinenfabrik, type GMbH 14.9), the volumetric flow is measured by an orifice flow meter. The gas distributor consists of 9 bubble caps arranged symmetrically as shown in 1 The solids are separated from the gas by two cyclones and returned into the riser via a siphon. The center of the solids inlet is located at a height of 1 m. The 0.1 m diameter inlet tube is attached to the riser at an angle of 45 degrees. The externally circulating solids flow rate is measured by weighing the increase of solids mass in a section of the downcomer pipe after shutting a butterfly valve.

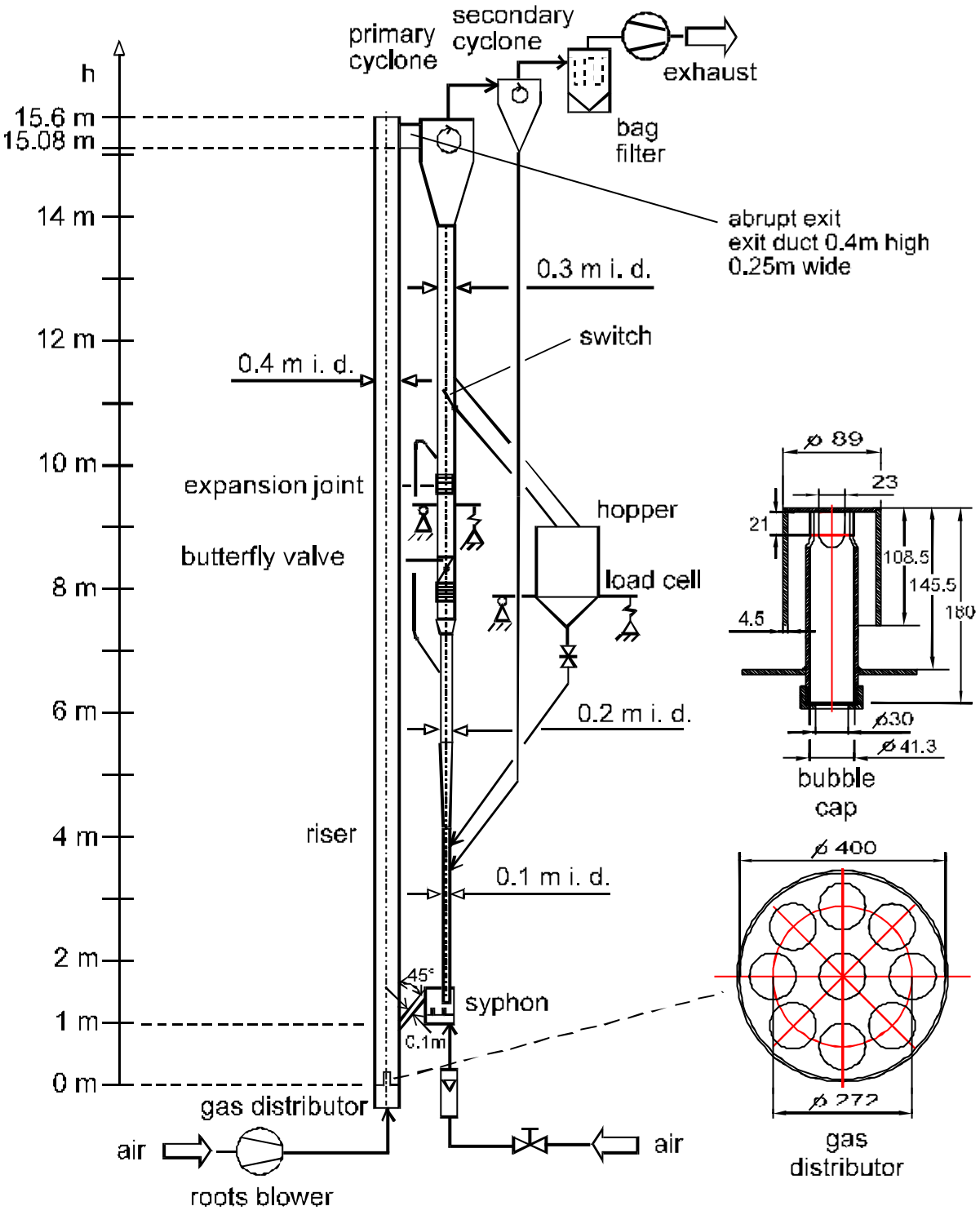

Figure. 1: Schematic of the CFB system with cylindrical riser. The height coordinate h is counted from the lower edge of the bubble cap where the fluidizing gas is entering into the bed.

Operating Conditions

Run Conditions	
Outlet Pressure (Pa)	100000
Temperature (K)	298

Gas Phase: Air *			
r (kg/m3) *	1.24	Run 1 QG(kg/s)	0.4524
μ (Pa.s)*	0.000018	Run 2 QG(kg/s)	0.6032

*** Outlet conditions**

Solid Phase: Quartz sand			
dpsv / dp50(micron)	140 / ???	Rhos (kg/m3)	2600
j (-)	Fill in	Run 1 QS(kg/m^2/s)	9
Size Distribution	See XLS sheet	Run 2 QS(kg/m^2/s)	17

* Gas physical properties are given for outlet conditions.

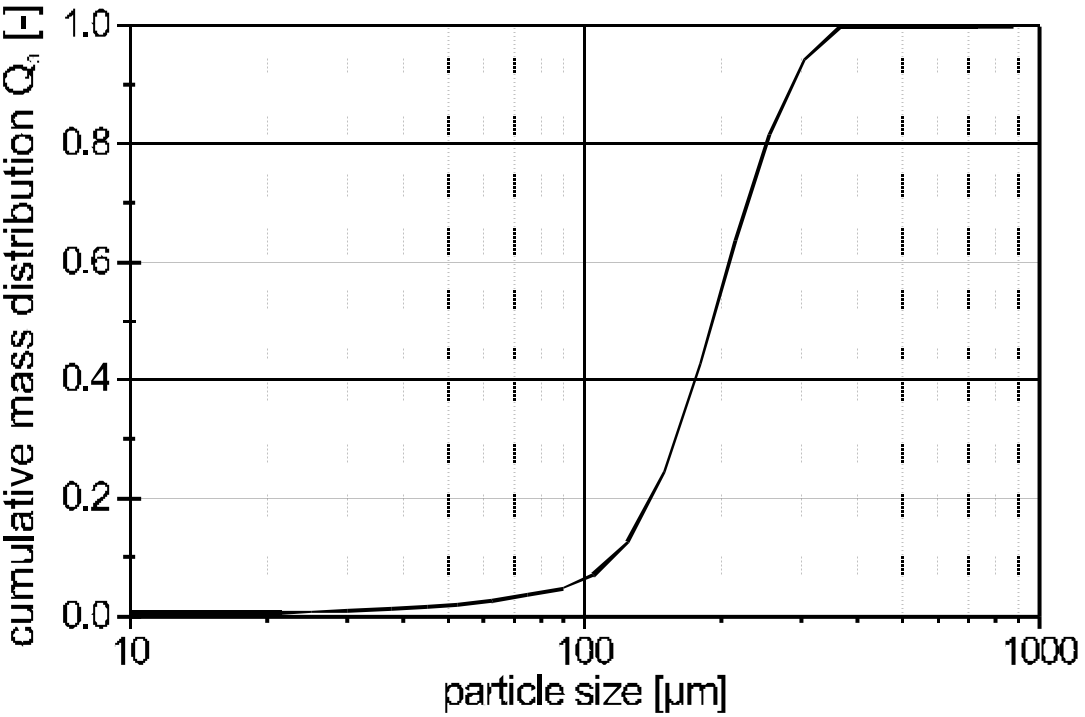

Figure. 2: Cumulative mass distribution

Experimental data

Three experimental data are reported :

- axial pressure drop
- radial solid volume concentration profile
- radial solid velocity profiles

Pressure drop measurements:

The facility is equipped with 27 pressure transducers (SENSYM, Inc.) along the riser to measure the axial pressure profile and 7 pressure taps in the return line and between siphon and riser to obtain the pressure loop. The sum of the individual differential pressure measurements was always compared with a measurement of the pressure drop along the riser in order to verify the accuracy of the local pressure measurements. The deviation of the time-averaged values was found to be less than 5%.The pressure profile along the riser was determined using 25 pressure transducers. The individual positions are given in table 1. The repeating accuracy for different measurements is about 5%.

No.	Height (lower) [m]	Height (upper) [m]
1	0.081	0.181
2	0.181	0.252
3	0.252	0.352
4	0.352	0.440
5	0.440	0.565
6	0.565	0.740
7	0.740	0.880
8	0.880	1.030
9	1.030	1.180
10	1.180	1.385
11	1.385	1.685
12	1.685	2.085
13	2.085	2.770
14	2.770	3.270
15	3.270	3.770
16	3.770	4.270
17	4.270	5.210
18	5.210	6.220
19	6.220	7.440
20	7.440	8.250
21	8.250	9.250
22	9.250	10.860
23	10.860	12.490
24	12.490	14.270
25	14.270	15.080

Table 1: Position of the pressure transducers along the riser

Solid volume concentration and solid velocity profiles :
Local solid concentrations and velocities were measured by fiber-optical probes depicted in Fig. 2 a. The local instantaneous solids concentration is deduced from the voltage signal U(t) by (cf. Hartge, et al., 1988):

$$c_v(t) = \left(\frac{U(t) - U_0(t)}{a_p} \right)^{1/n}$$

where $U_0(t)$ is the signal level at $c_v = 0$.

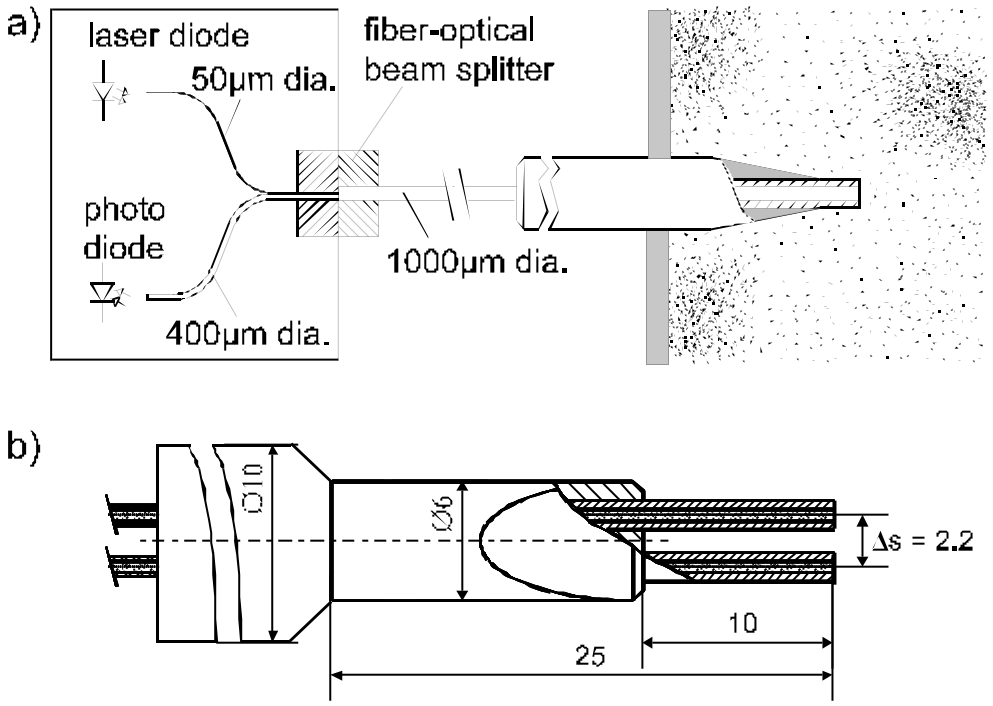

Figure 2: a) Operation principle of the fiber optical reflection probe system
b) Sketch of the two-channel probe head (dimensions in mm)

An optical probe with a two-channel head (fiber diameter 1 mm) depicted in Fig. 2 b was used to measure local solids velocities by applying the cross correlation method. Fig. 3. shows a top view of the CFB-unit. The angle between solids return line and fibre optical probe φ is listed in the tables below.

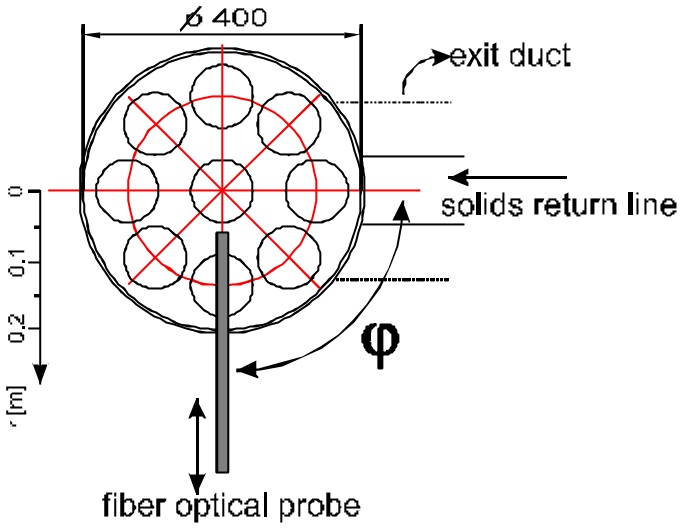

Figure 3: Arrangement of the fiber optical probe measurement, φ is the angle between solids return line an fiber optical probe

Local solids concentration measurements are available at following positions:

Case A

Height [m]	j	**Measurements carried out at radius r [m]**
0.19	100°	0, 0.1, 0.15, 0.165, 0.18, 0.19, 0.195
0.26	100°	0, 0.1, 0.15, 0.165, 0.18, 0.19, 0.195
0.32	100°	0, 0.1, 0.15, 0.165, 0.18, 0.19, 0.195
0.42	100°	0, 0.1, 0.15, 0.165, 0.18, 0.19, 0.195
0.72	100°	0, 0.1, 0.15, 0.165, 0.18, 0.19, 0.195
4.90	90°	0, 0.005, 0.01, 0.03, 0.05, 0.07, 0.09, 0.11, 0.13, 0.15, 0.16, 0.17, 0.18, 0.185, 0.19, 0.195
6.40	90°	0, 0.005, 0.01, 0.03, 0.05, 0.07, 0.09, 0.11, 0.13, 0.15, 0.16, 0.17, 0.18, 0.185, 0.19, 0.195
8.43	90°	0, 0.005, 0.01, 0.03, 0.05, 0.07, 0.09, 0.11, 0.13, 0.15, 0.16, 0.17, 0.18, 0.185, 0.19, 0.195

Case B

Height [m]	j	**Measurements carried out at radius r [m]**
3.00	90°	0, 0.005, 0.01, 0.03, 0.05, 0.07, 0.09, 0.11, 0.13, 0.15, 0.16, 0.17, 0.18, 0.185, 0.19, 0.195
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Local solids velocity measurements are available at following positions:

Case A

Height [m]	j	**Measurements carried out at radius r [m]**
4.90	90°	0, 0.005, 0.01, 0.03, 0.05, 0.07, 0.09, 0.11, 0.13, 0.15, 0.16, 0.17, 0.18, 0.185, 0.19, 0.195
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Case B

Height [m]	j	**Measurements carried out at radius r [m]**
3.00	90°	0, 0.005, 0.01, 0.03, 0.05, 0.07, 0.09, 0.11, 0.13, 0.15, 0.16, 0.17, 0.18, 0.185, 0.19, 0.195
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Calculation Request

- Axial profile of pressure along the CFB
- Radial profiles of solid volume concentration and solid velocity at different elevations

Calculation Request

- Pressure profiles along the riser
- Profiles of net mass flux along the riser diameter 1.325 m and 7m above inlet.