Investigating Bubble Dynamics In A Semi-cylindrical Gas-solid Fluidized Bed

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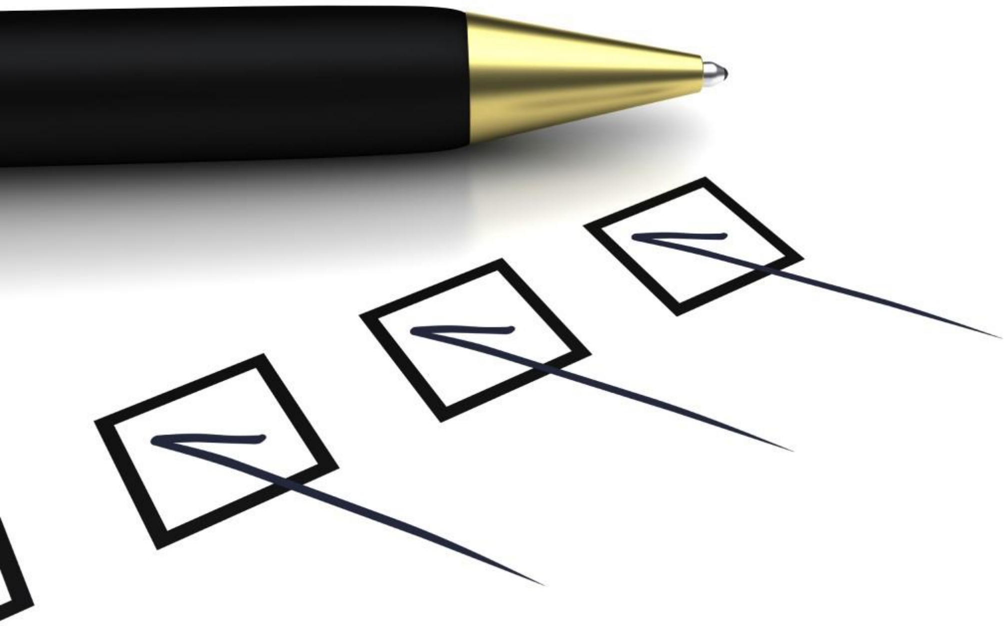

- **Introduction**
- Literature review
- Experimental procedure
- Data analysis
- Results & discussion
- Conclusion

Problem statement

Lack of information

More knowledge about hydrodynamic

Accurately design and optimal use

Bubble size
Bubble velocity

2D beds are qualitative and of limited applicability to 3-D beds

Suitable for direct visual observation

- Vibration of the bed
- Rotation of the bed
- Turbulence promoters

Enhance the fluidization quality

Non cylindrical fluidized beds

- Operation over a wide range of gas superficial velocity
- Possibility of fluidizing a wide range of particles of different sizes or densities
- Intensive particle mixing

Semi-cylindrical fluidized bed

Literature review

Ref.	Bed type	Method	Particle	Major findings
Hatate et al. (1985)	Semi cylindrical	Imaging	Sand	• Application of bubble growth expression of 3D bed for semi cylindrical fluidized • Application of bubble rise velocity expression of 3D bed for semi cylindrical fluidized
Singh et al. (2005 & 2006)	Semi-cylindrical Cylindrical Hexagonal Square	Pressure drop	Dolomite Coal	• Under similar operating conditions minimum bubbling velocity is maximum in case of either semi-cylindrical or hexagonal fluidized beds and minimum in case of square one • Also, bed fluctuation is maximum in case of square bed and minimum in semi-cylindrical one.

Literature review

Ref.	Bed type	Method	Particle	Major findings
Escudero et al. (2011& 2012)	Cylindrical	Pressure signals Imaging	Glass beads Walnut shell Corncob	• Minimum fluidization velocity is not affected by the change in bed height, but increases by material density • Increasing the H/D ratio enhanced bubble coalescence creating slugs that flow thorough the center of the bed, producing regions of low gas holdup near the walls of the fluidized bed • Bed hydrodynamics were similar for all bed heights, but differed when the material density was changed
Badday et al. (2014)	Cylindrical	Pressure signals	Sand	• Minimum fluidization velocity increased as the particle size increased • The bed voidage increased in the bottom section of bed and decreased in the other sections with increasing the gas superficial velocity
Shabanian and Chaouki (2015)	Cylindrical	Pressure signals Fiber optic	Coated sugar	• Minimum fluidization velocity increases with interparticle forces • Gas is more prone to pass through the bed in the emulsion phase when interparticle forces increase • Enhancing interparticle forces will increase the bubbling to turbulent regime transition velocity

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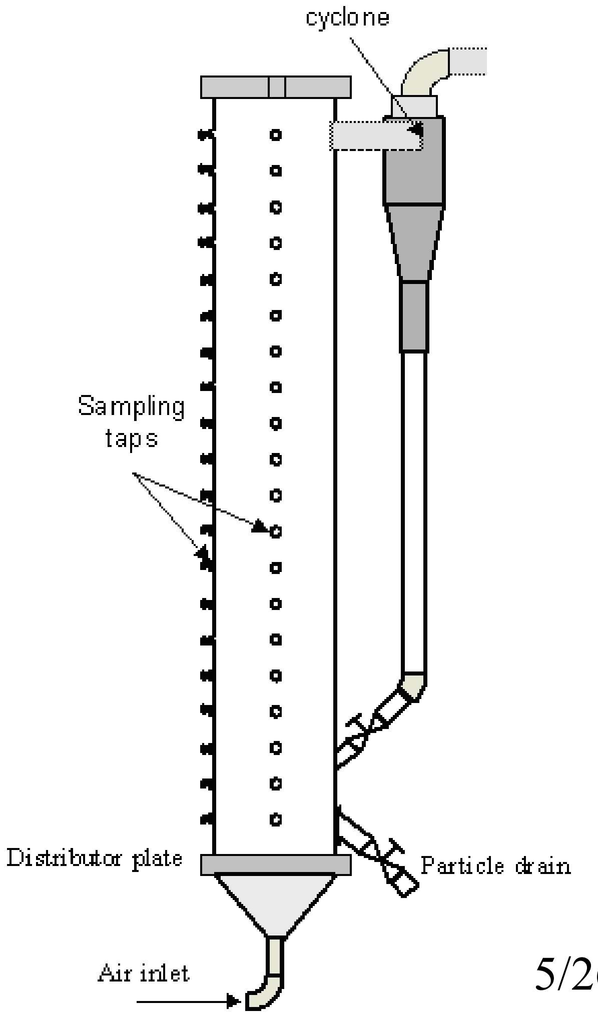
Experimental setup

	Cylindrical	Semi-cylindrical
Height (cm)	200	100
Diameter (cm)	14	14
Type of distributor	perforated	perforated



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Experimental setup

Cylindrical	Semi-cylindrical	
		

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Particle properties

	Density (kg/m^3)	Size (µm)
Glass bead I	2500	120
Glass bead II	2500	290
Glass bead III	2500	450

Initial bed height of 21 cm (L/D =1.5)

Geldart group B

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Experimental methods

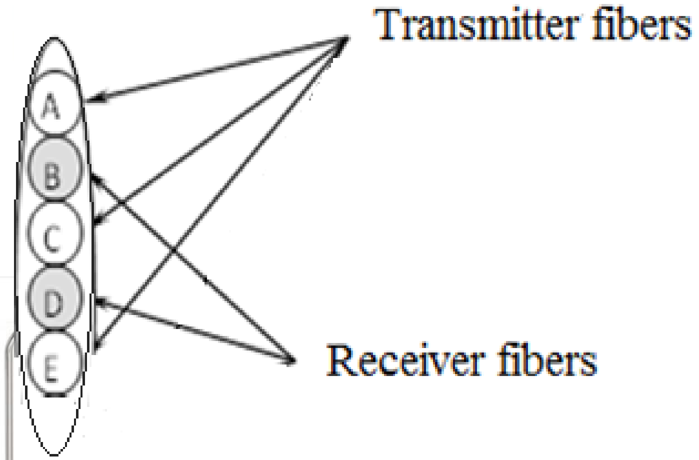
❑ Pressure probe

-1 – 10 bar

- ➢ 14 cm above the distributor plate (L/D =1)

❑ Fiber optic

- ➢ 14 cm above the distributor plate (L/D=1)



❑ Digital image

120 frames per seconds

Test duration: 30 s

Frequency of 10000 Hz

Test duration: 180 s

Pressure signal analysis

Time domain

Standard deviation

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}}$$

Frequency domain

Fourier transform

$$X(f) = \sum_{i=1}^{N} x(i)\exp(-j2\pi i f)$$

Welch

$$P_{xx}^{n}(f) = \frac{1}{N_L U}\left|\sum_{i=1}^{N_L} x_n(i)w(i)\exp(-j2\pi i f)\right|^2$$

$$U = \frac{1}{N_L}\sum_{i=1}^{N_L} w^2(i)^2$$

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Fiber optic signal analysis

Bubble velocity

Bubble size

Bed voidage

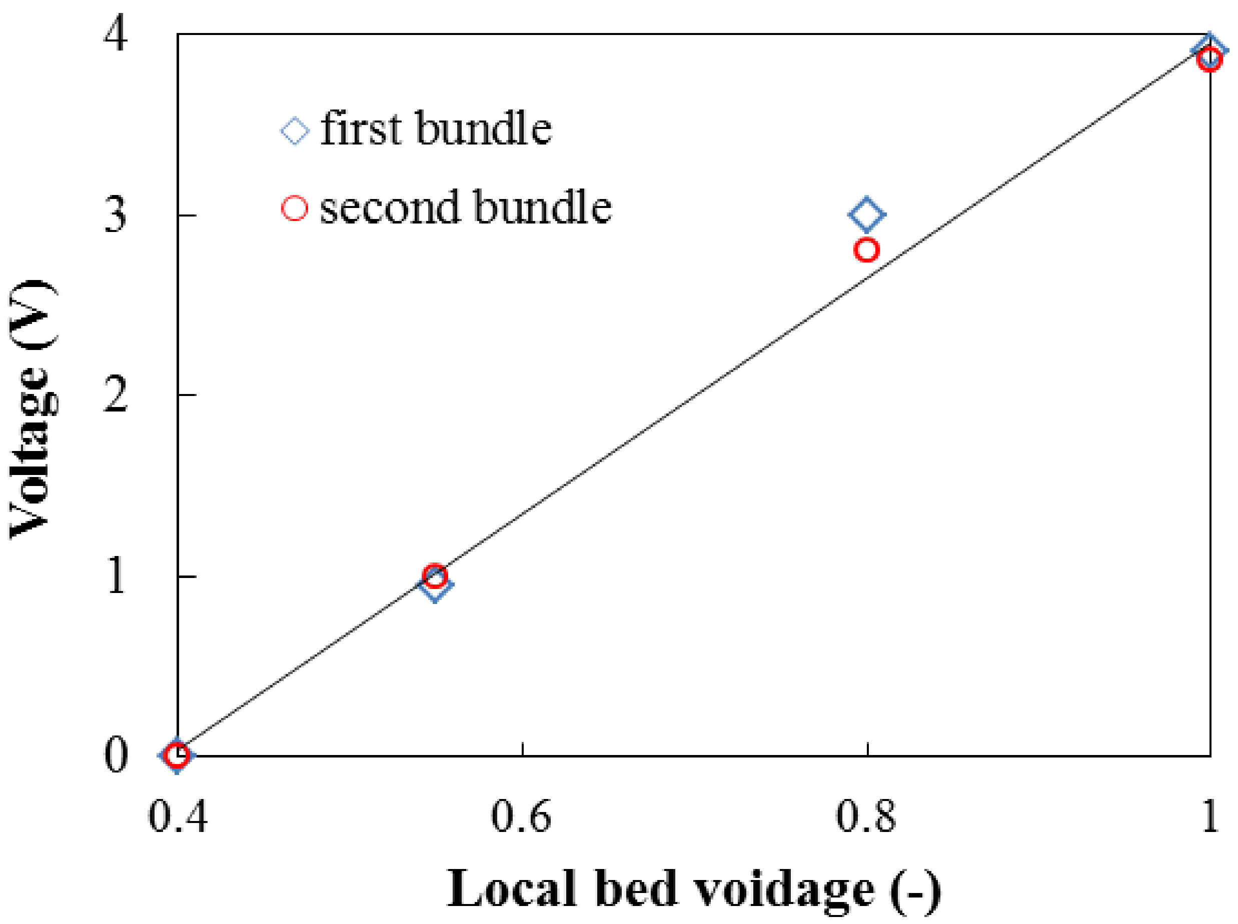

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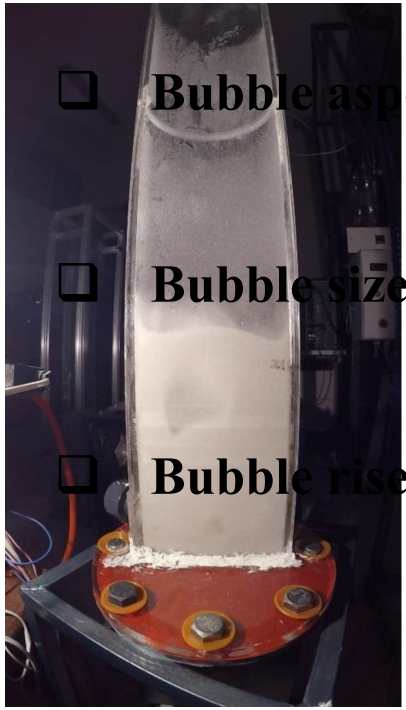
Image processing

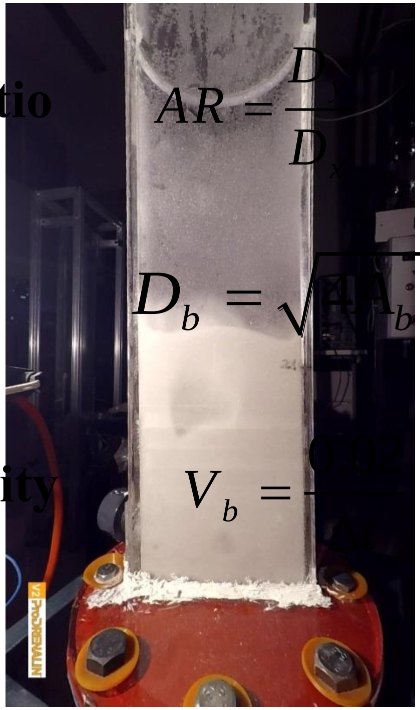
Video
- ProDRENALIN

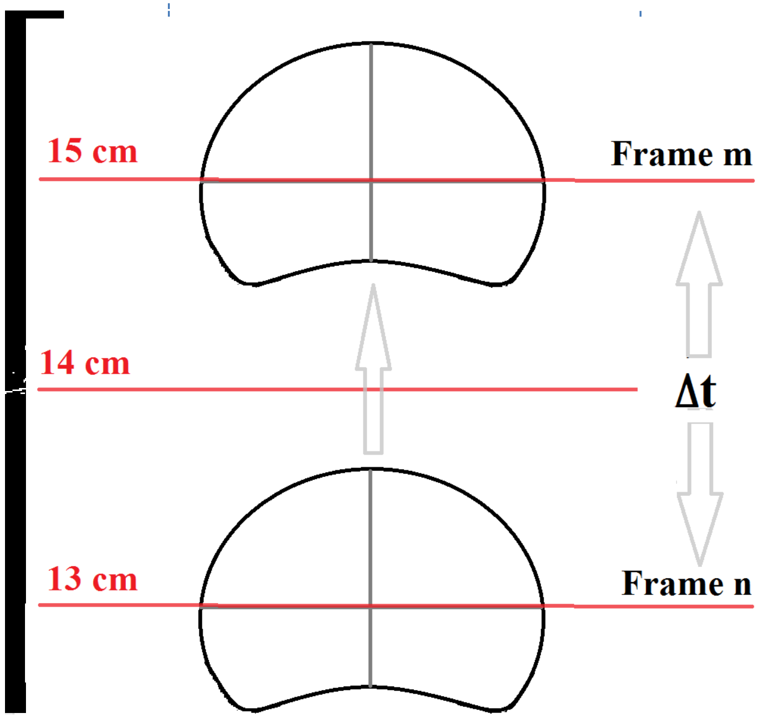
Removing fish eye
- Video to JPG Converter

Picture
- Image j



- **Bubble aspect ratio** $AR = \frac{D_y}{D_x}$
- **Bubble size** $D_b = \sqrt{4A_b/\pi}$
- **Bubble rise velocity** $V_b =$





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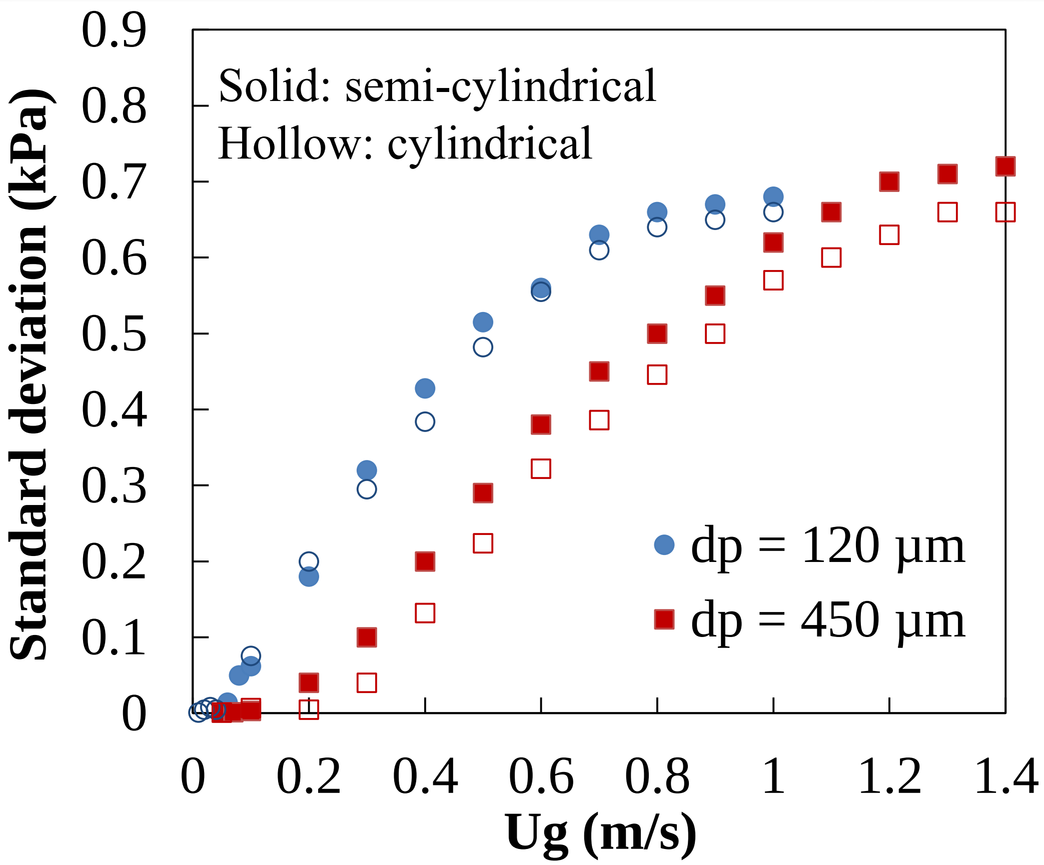
Standard deviation of pressure fluctuations



Type of bed	Semi-cylindrical			Cylindrical		
d_p (µm)	120	290	450	120	290	450
Experimental U_{mf} (m/s)	0.021	0.089	0.210	0.02	0.090	0.205
Wen and Yu (m/s)	0.014	0.082	0.196	0.014	0.082	0.196

C. Wen, Y. Yu, A generalized method for predicting the minimum fluidization velocity, AIChE Journal, 12 (1966) 610-612.

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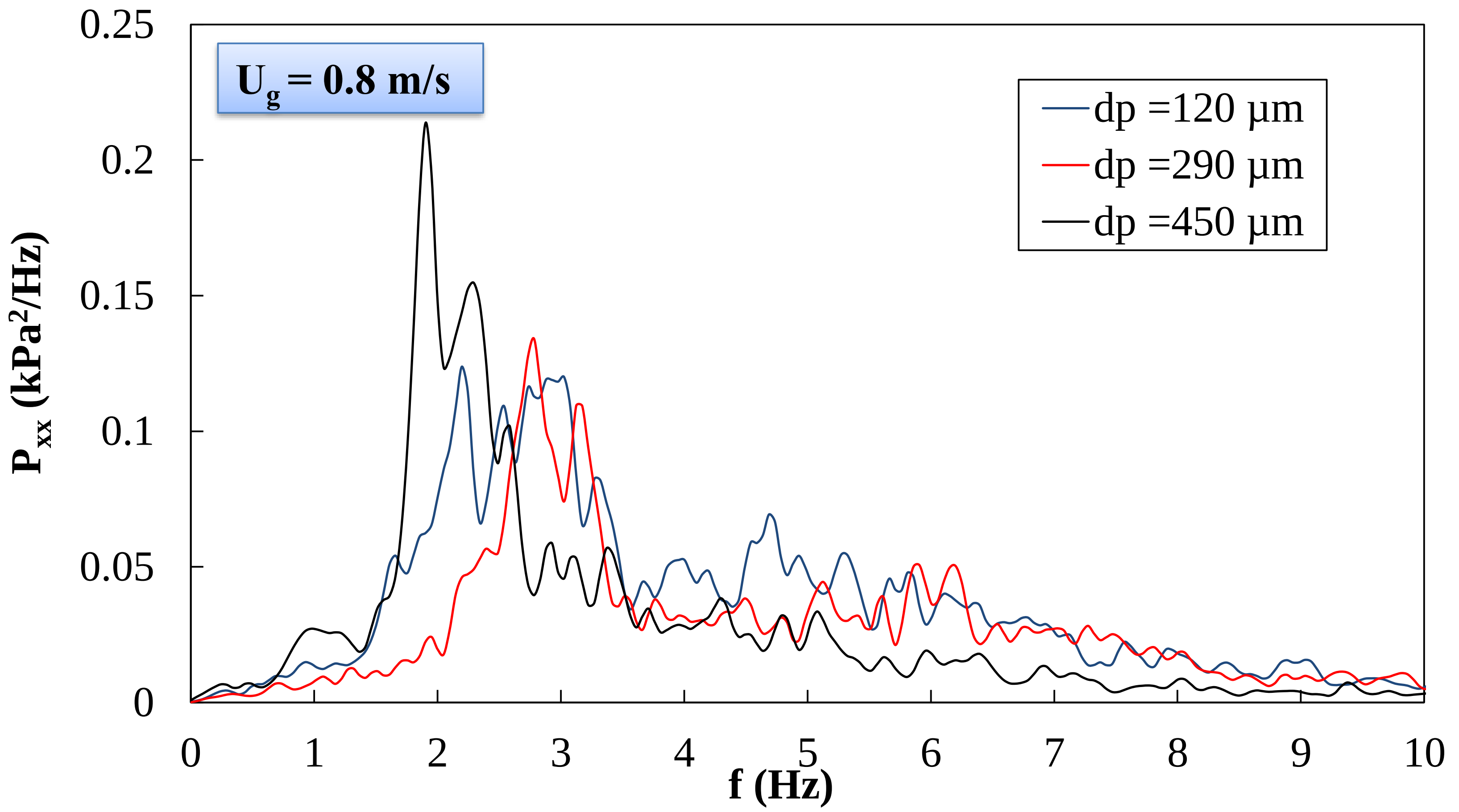
Power spectral density function of pressure fluctuations



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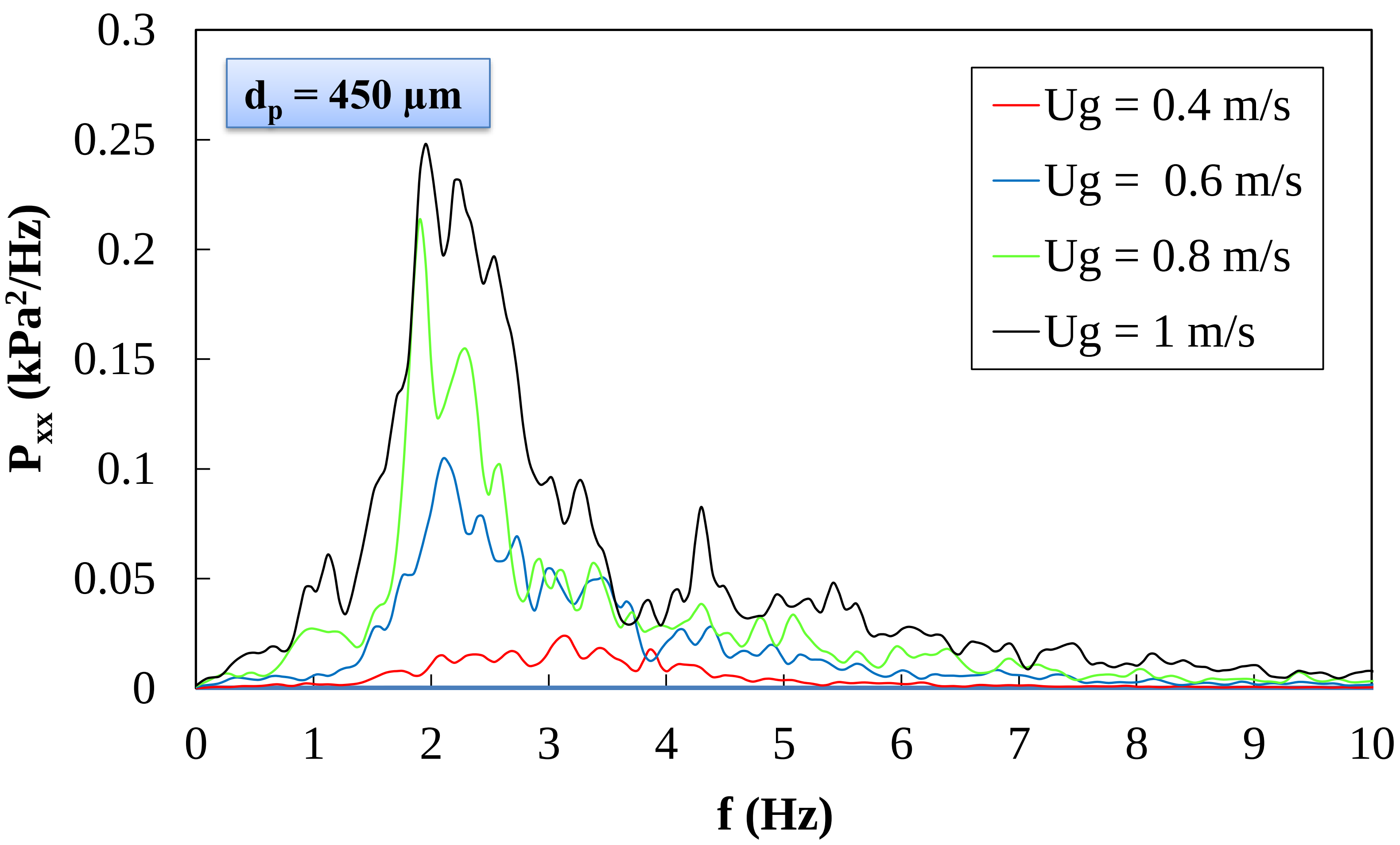
Power spectral density function of pressure fluctuations



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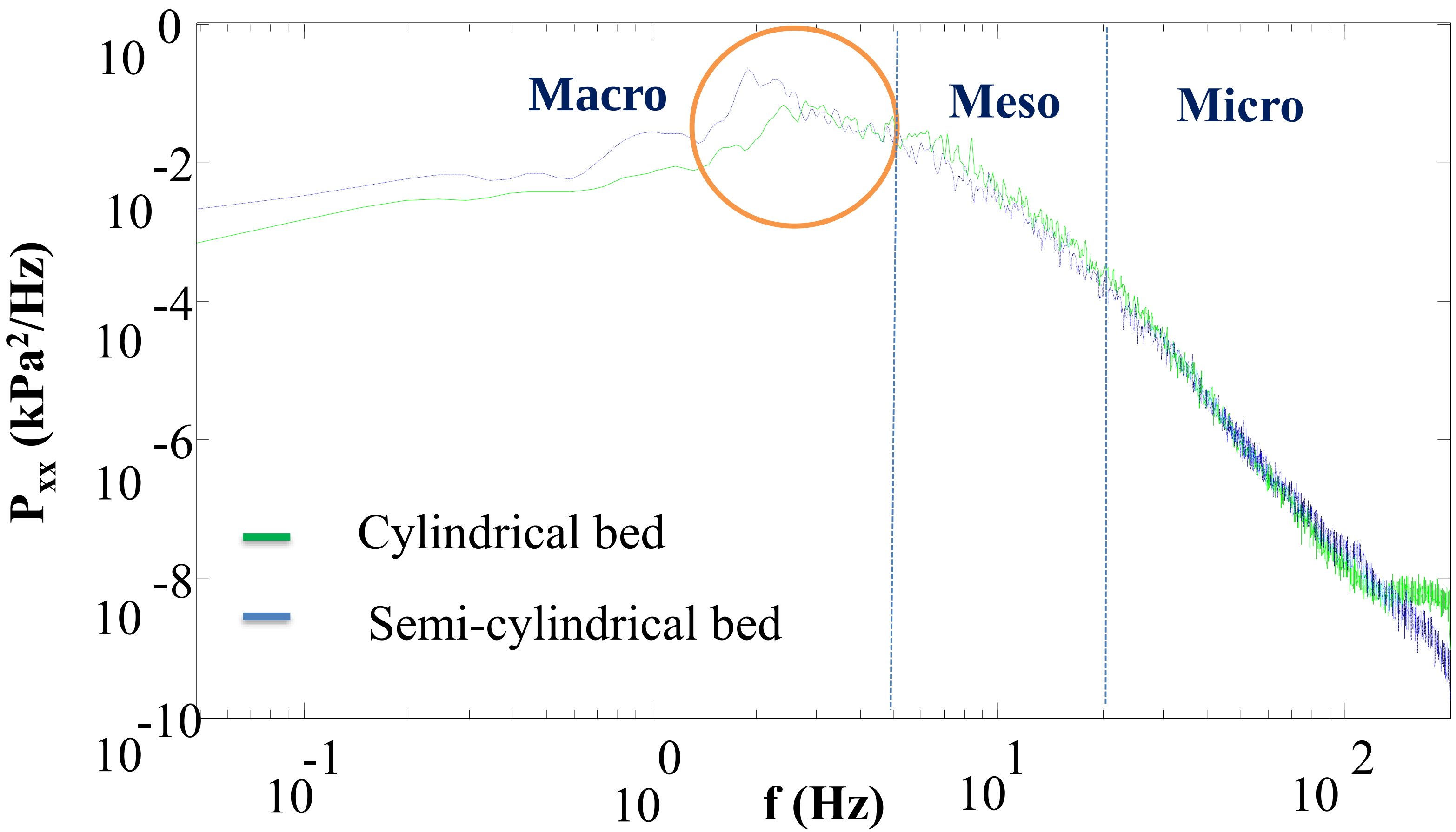
PSDF of pressure in semi-cylindrical Vs. cylindrical



d_p = 450 μm & U_g = 0.8 m/s

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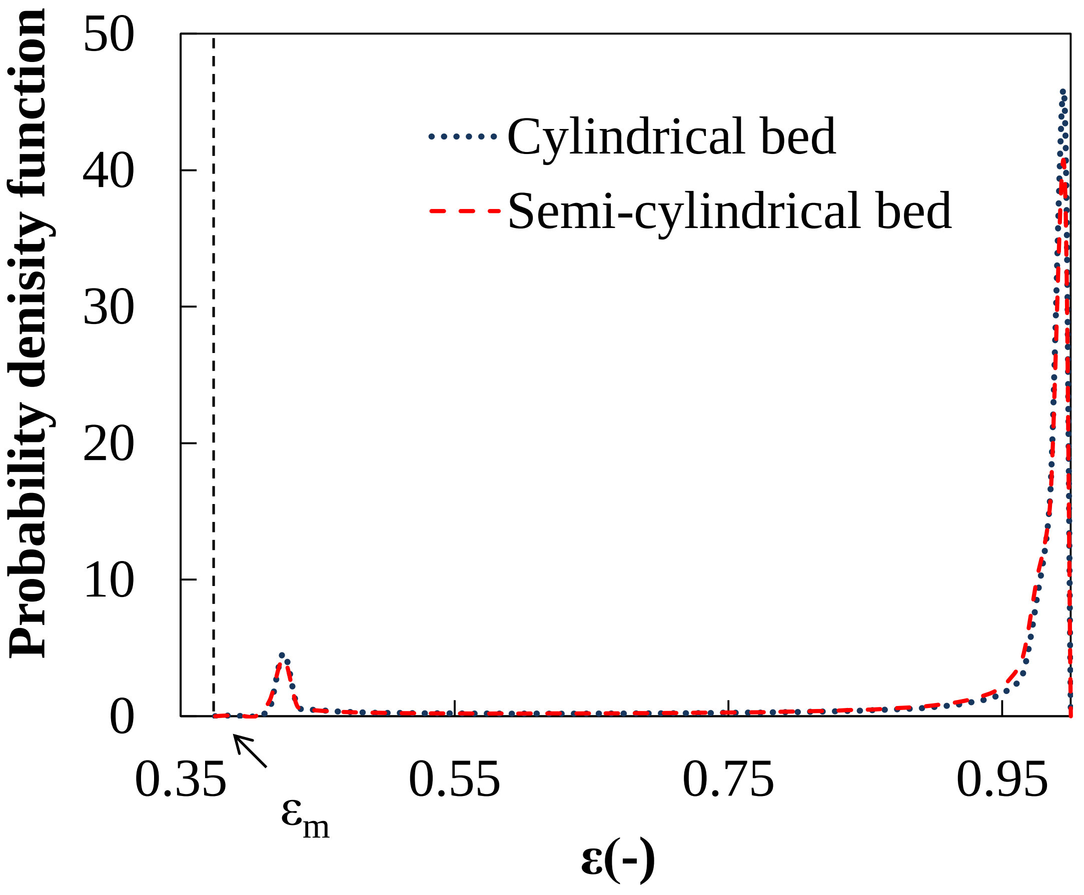
Distribution of local bed voidage



d_p = 450 µm & U_g = 0.6 m/s

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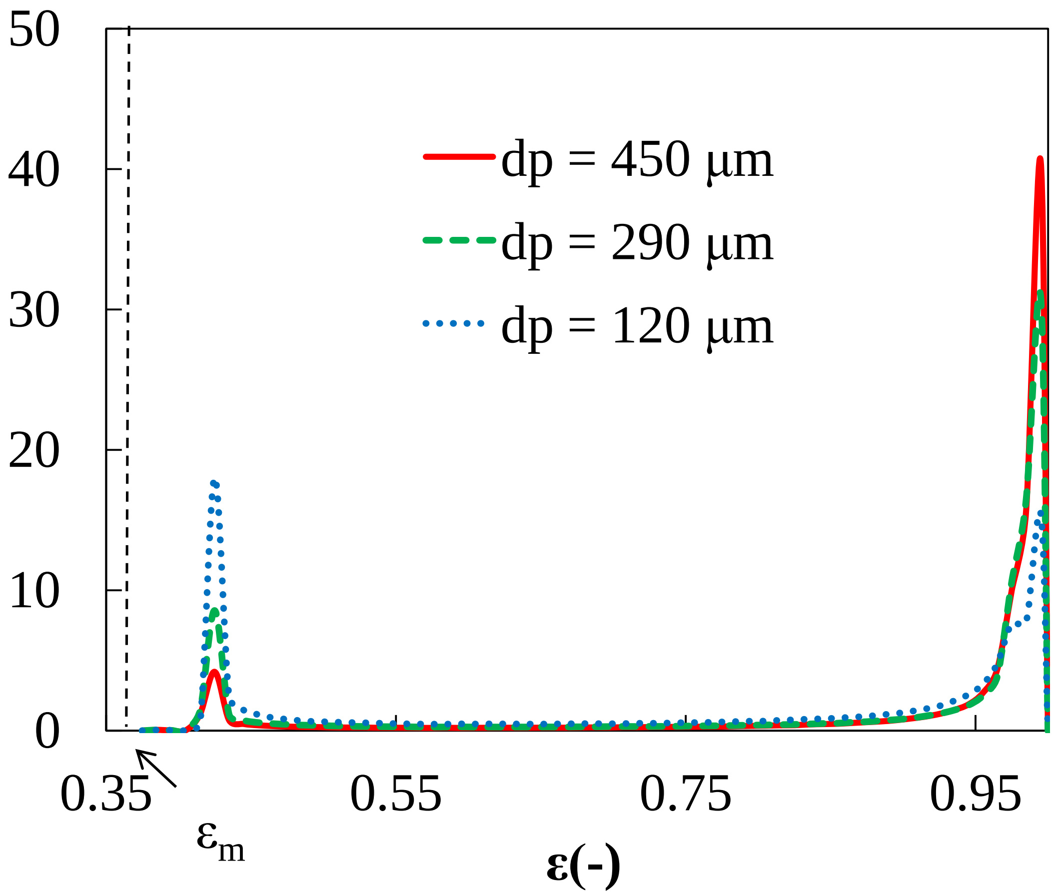
Distribution of local bed voidage



Semi-cylindrical bed at U_g = 0.6 m/s

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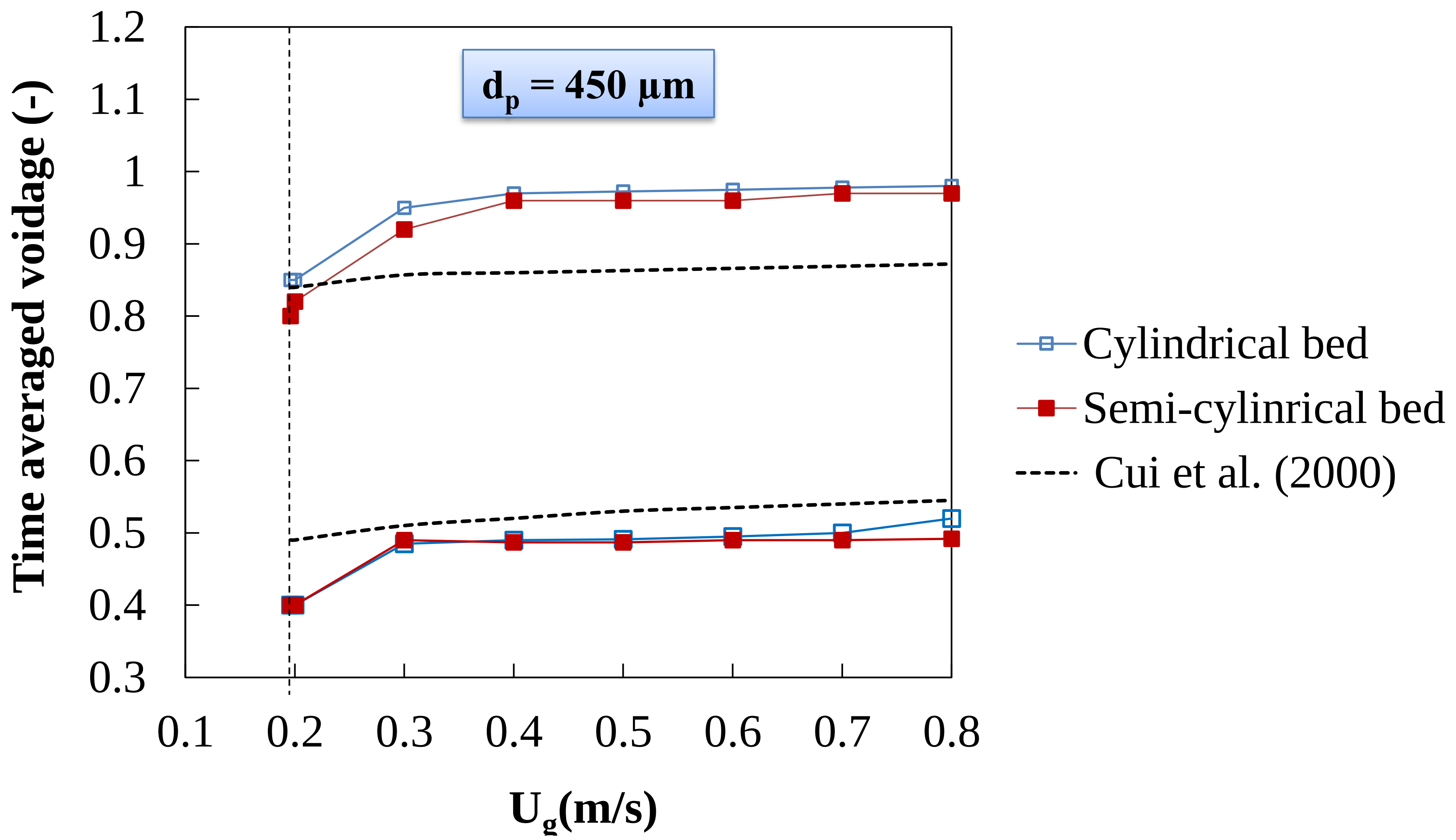
Time-averaged voidages for particle of 450 µm



H. Cui, N. Mostoufi, and J. Chaouki, "Characterization of dynamic gas–solid distribution in fluidized beds," Chemical Engineering Journal, vol. 79, pp. 133-143, 2000.

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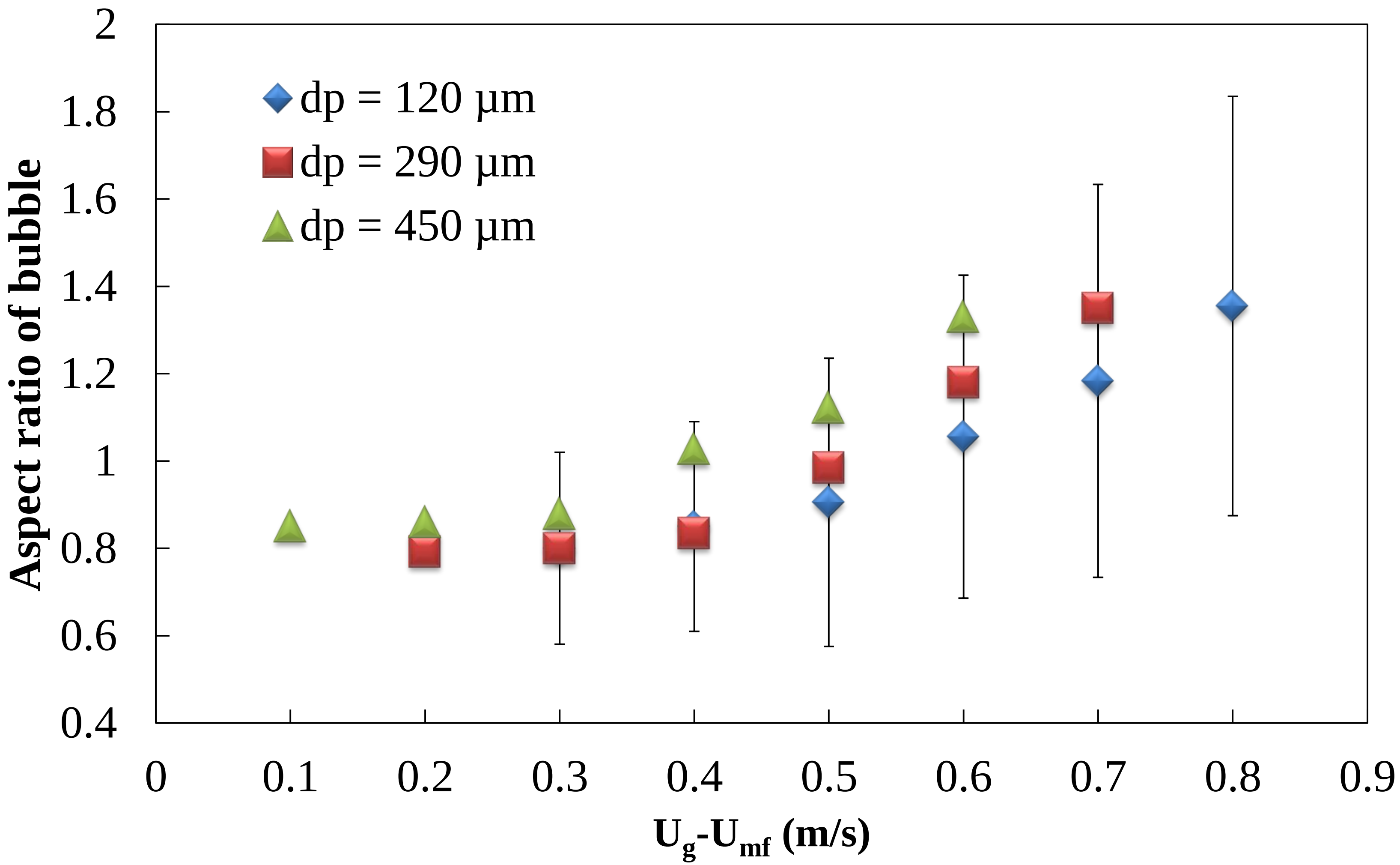
Bubble aspect ratio of semi-cylindrical bed



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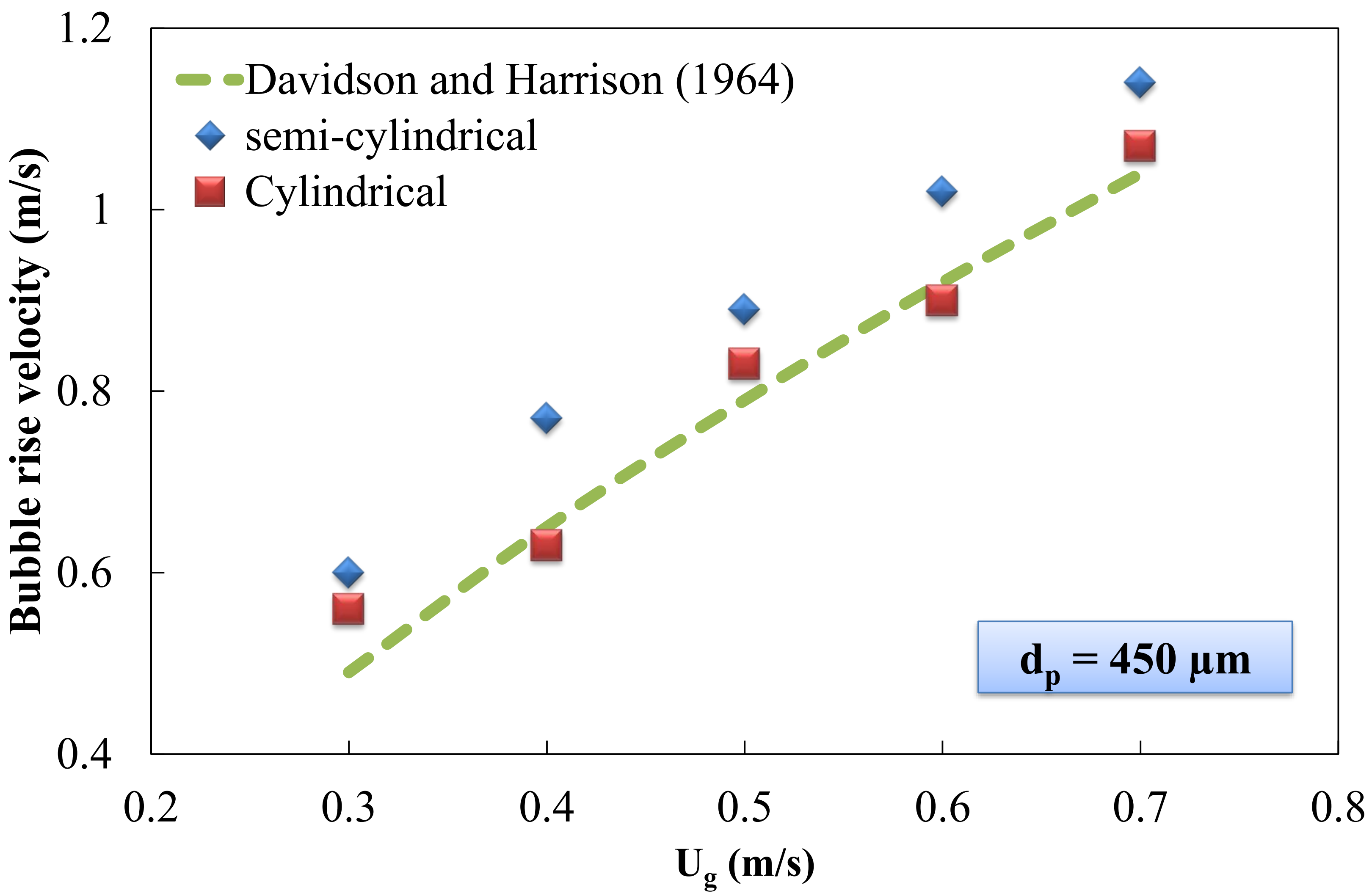
Bubble rise velocity



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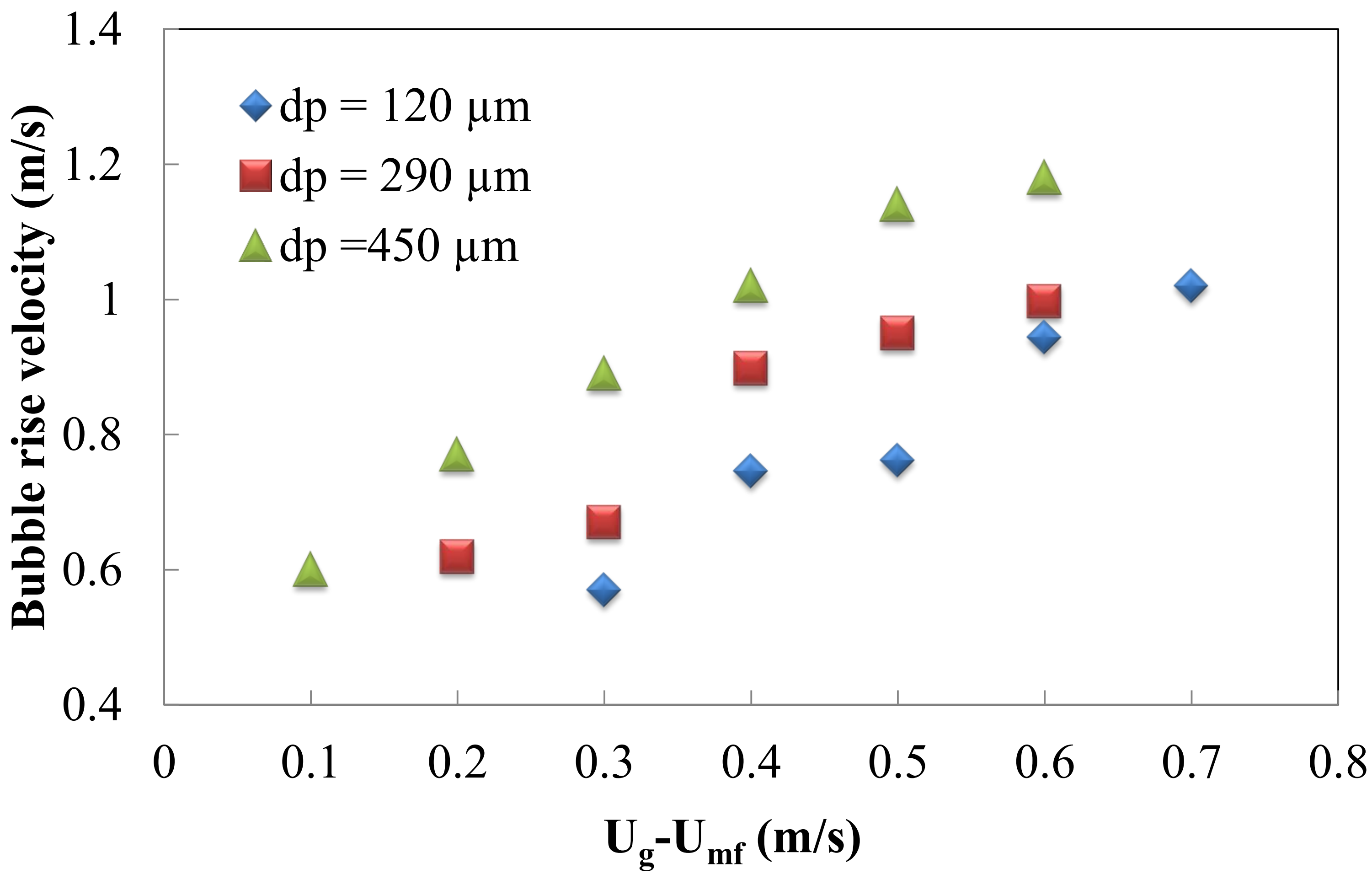
Bubble rise velocity of semi-cylindrical bed



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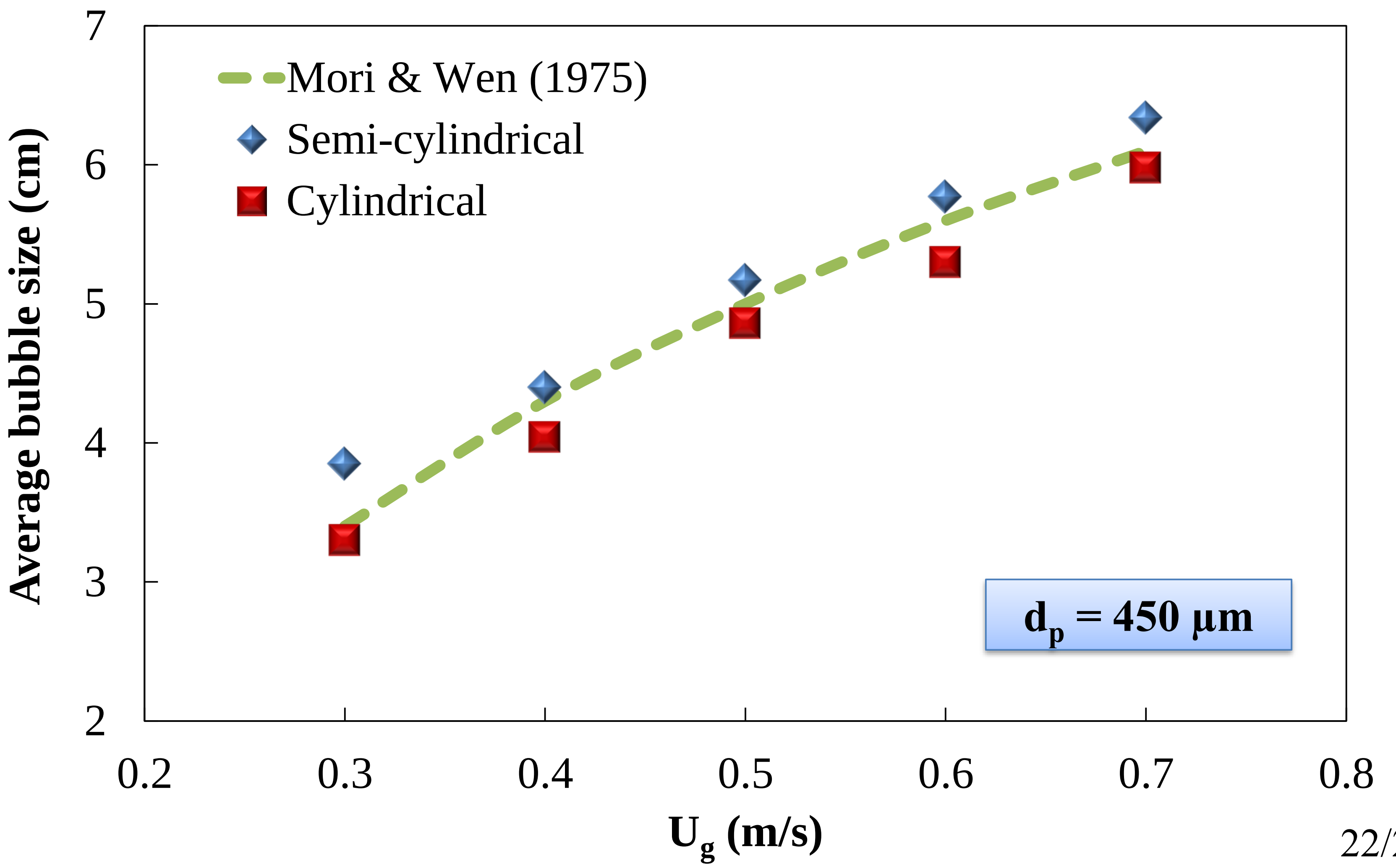
Average bubble size



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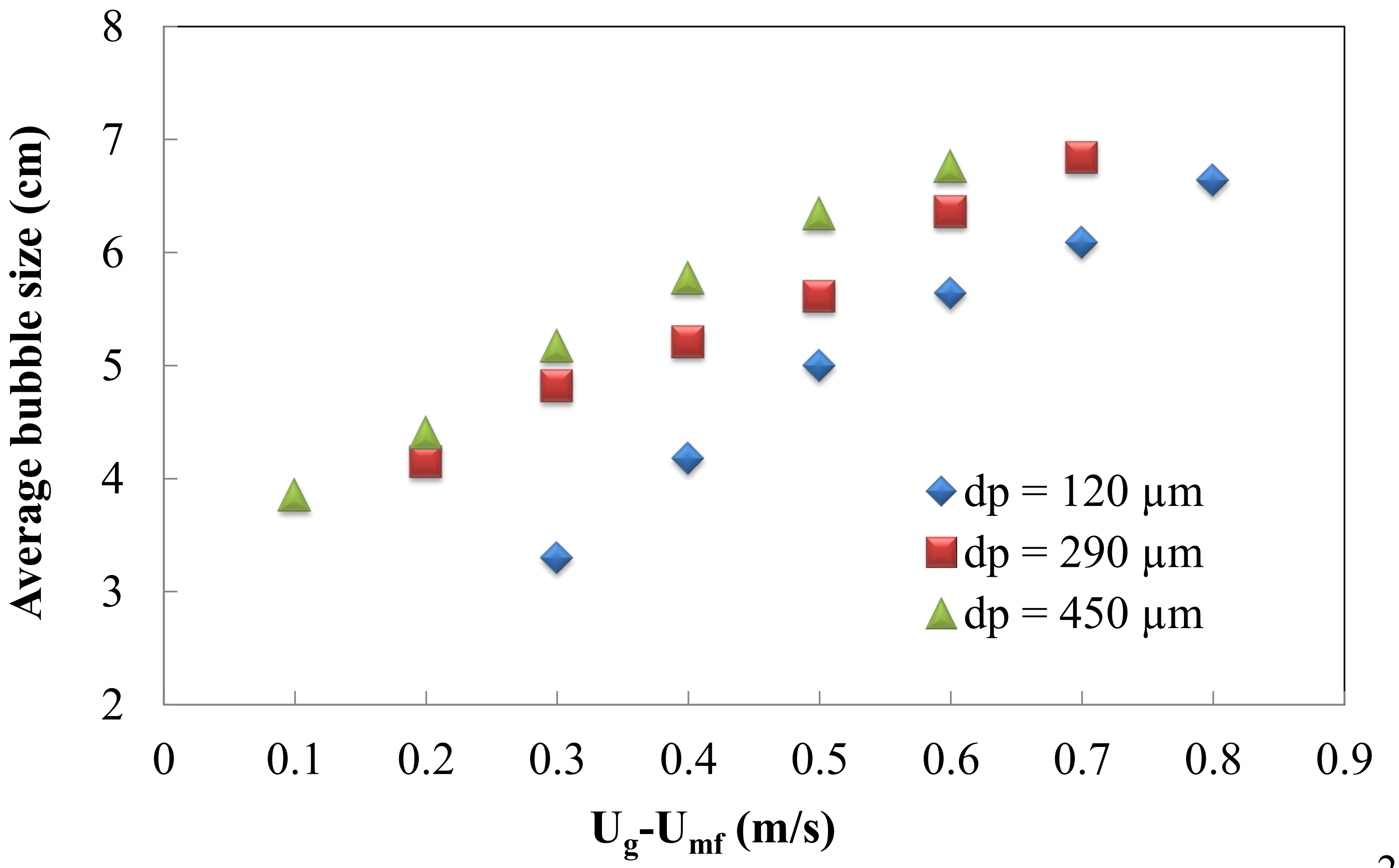
Average bubble size



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Conclusions

1. According to standard deviation results, U_{mf} and U_c were independent of the cross-section of fluidized bed.

2. PSDF of pressure fluctuations showed that increasing the gas velocity leads to formation of larger clusters and increases number and size of bubbles in the bed.

3. PSDFs in both beds are very similar with minor differences in intensity in low frequencies at high gas velocity. Thus, number of large bubbles in the semi-cylindrical bed is slightly higher than in the cylindrical bed at high velocity.

Conclusions

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4. Minor effect of cross-section of fluidized bed on average bubble size and rise velocity was observed when compared at the same particle size and superficial gas velocity.
5. Mori and Wen for bubble growth and Davidson and Harison for bubble rise velocity were found to be applicable to both beds.
6. Results indicated that the hydrodynamics and bubble dynamics parameters in semi-cylindrical fluidized bed is in compliance with the cylindrical fluidized bed.
7. Measuring bubble parameters in the semi-cylindrical bed was much easier than in the cylindrical bed. So semi-cylindrical bed is a very useful tool for being employed for cold model works in laboratories instead of two dimensional or cylindrical fluidized.


Thanks for your attention