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Development and study of measurement methods for bogging in a fluidized bed

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Development and Study of Measurement Methods for Bogging in a Fluidized Bed

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Background

- **Wet gas-fluidized beds may suffer from bogging, a significant degradation in fluidization quality**
- **This results from particle-particle adhesion caused by liquid bridges**
- **Rapid and accurate bogging detection is essential to allow for corrective action**

Objectives

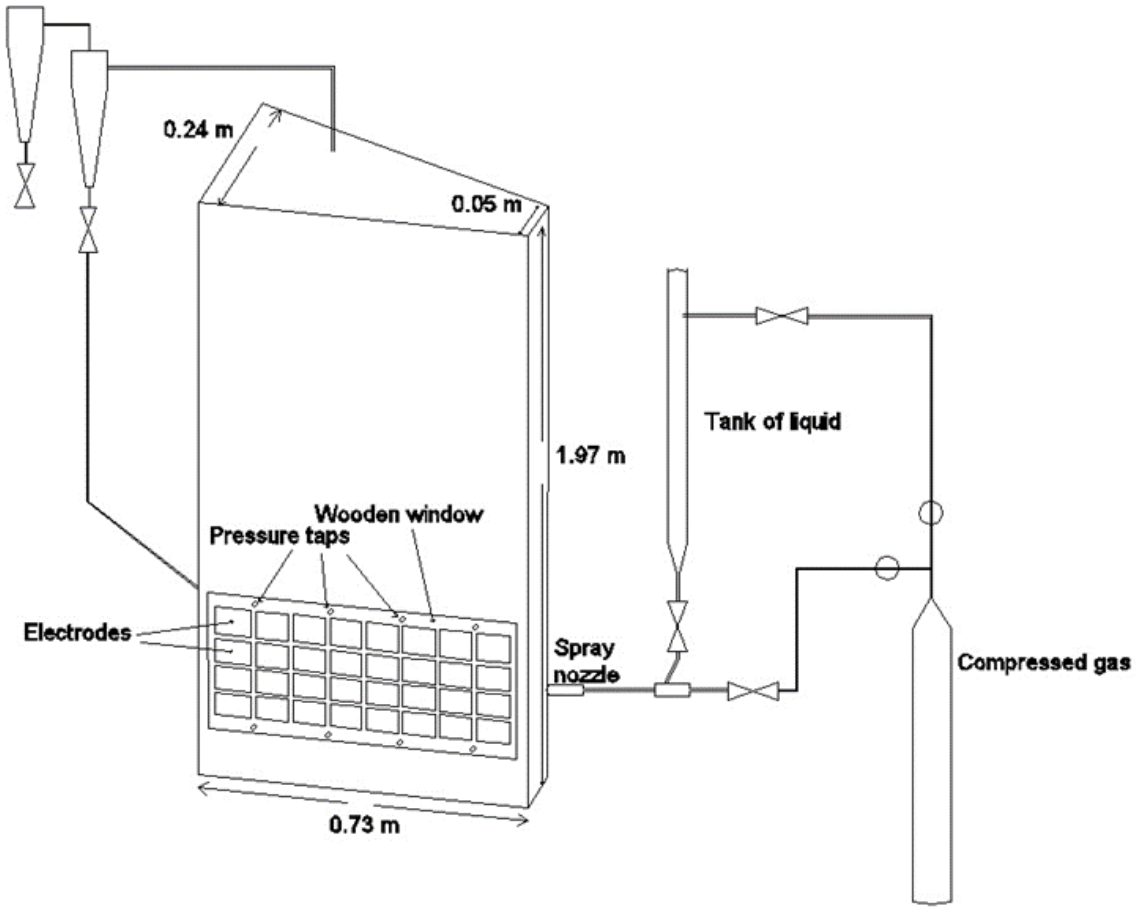
1) Determine the bogging transition from its impact on the distribution of injected liquid on fluidized particles.

2) Determine the impact of bogging on gas bubble properties.

3) Develop and test methods for the detection of bogging from fluctuations of the bed pressure gradient.

4) Measure and model the impact of bogging on the transmission of sound through a fluidized bed.

Experimental setup



- Coke particles (d_{psm} = 144 μm)
- Air for fluidization
- VoltEsso oil for bogging liquid

Measuring Equipment

- Capacitance sensors:
  - Bubbles
  - Liquid distribution
- Pressure transducers
  - In bed pressure gradient
  - 1 kHz
- Speed of sound
  - Speaker in freeboard
  - Microphones in bed

Impact of bogging on distribution of sprayed liquid on bed particles

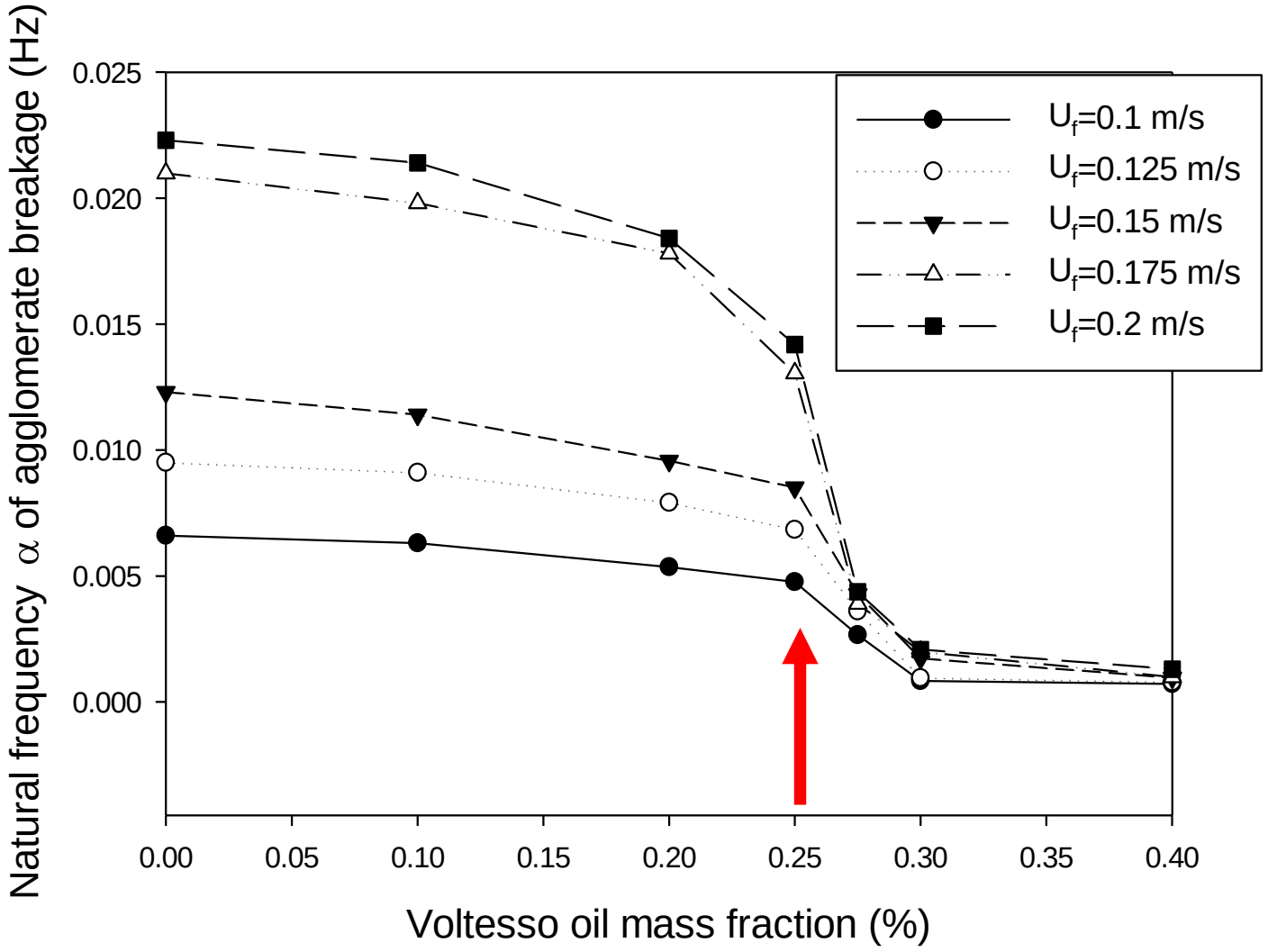
- **Sprayed liquid forms wet agglomerates with bed particles**

- **Kinetics of wet agglomerate breakup:**
  - **fraction of the injected liquid that has been released from agglomerates at time t:**

$$g(t) = 1 - e^{-\alpha t}$$

  - **α is natural frequency of agglomerate breakage**
  - **Fast agglomerate breakup (high α) is better for the process**

Impact of bogging on distribution of sprayed liquid on bed particles



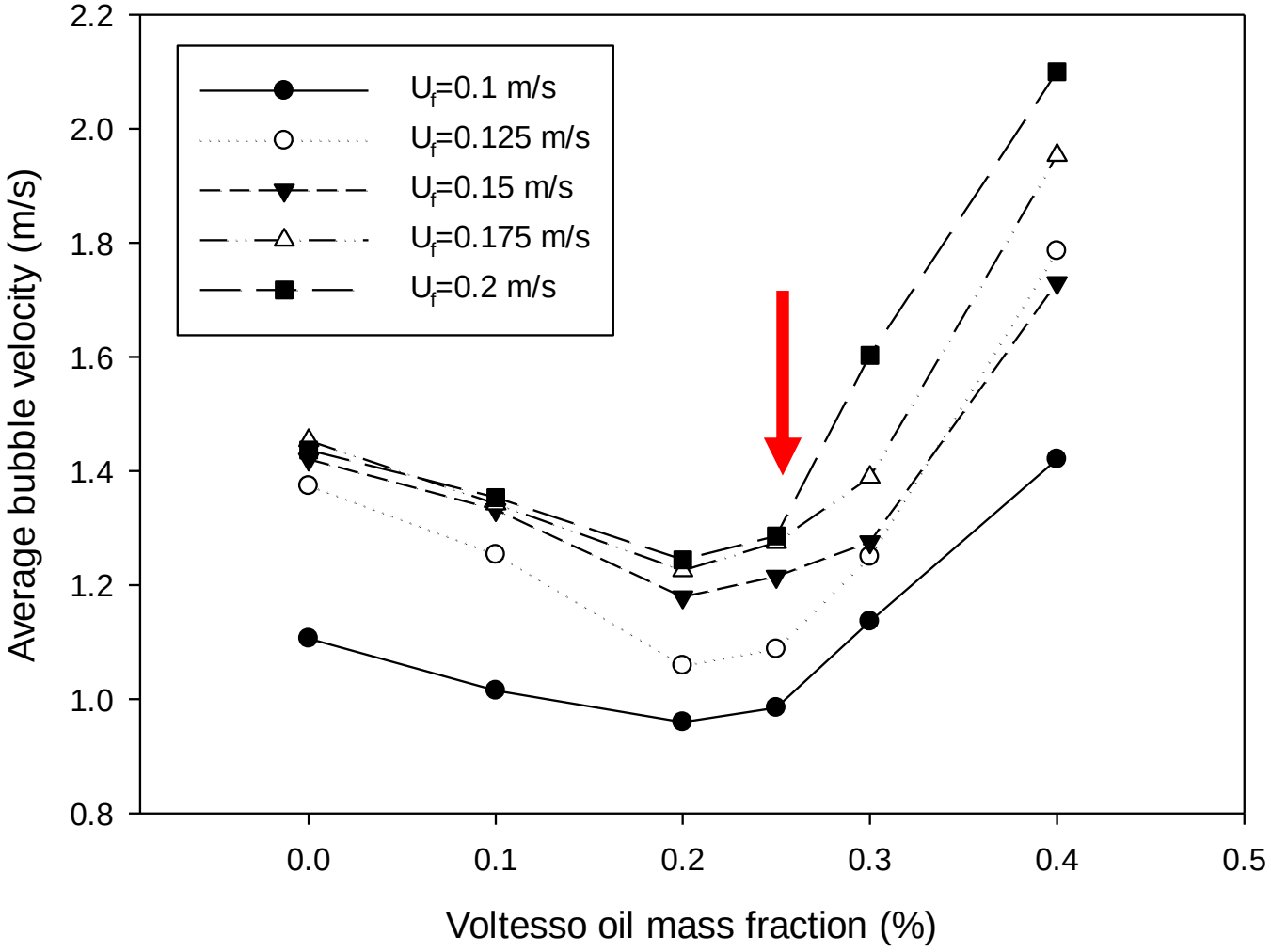
Impact of bogging on gas bubbles

Methods to obtain bubble properties from capacitance signals:

- **Capacitance time series due to passing bubbles simulated with Comsol**
- **Time series used to train neural networks**

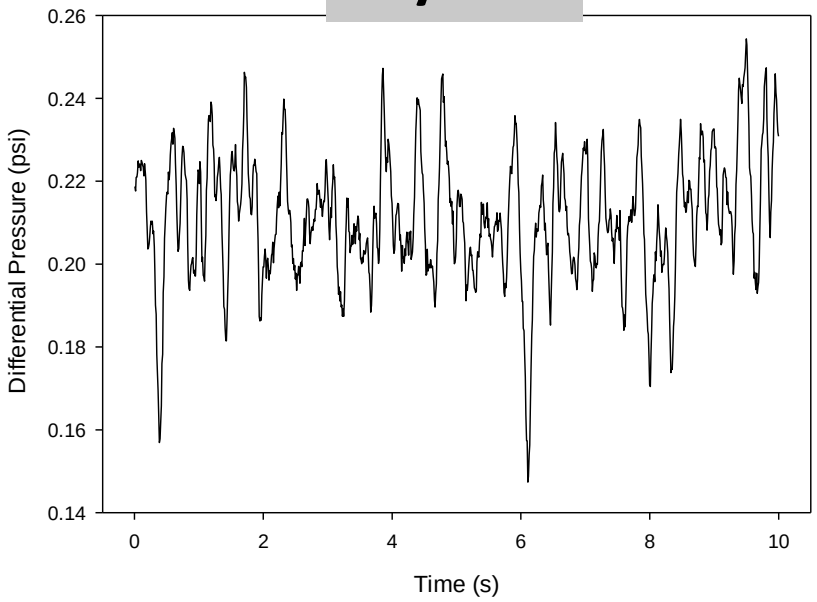
- **Neural networks then used to predict from measured capacitance:**
  - **bubble height**
  - **bubble frontal diameter**
  - **distance from the wall**

Impact of bogging on gas bubbles

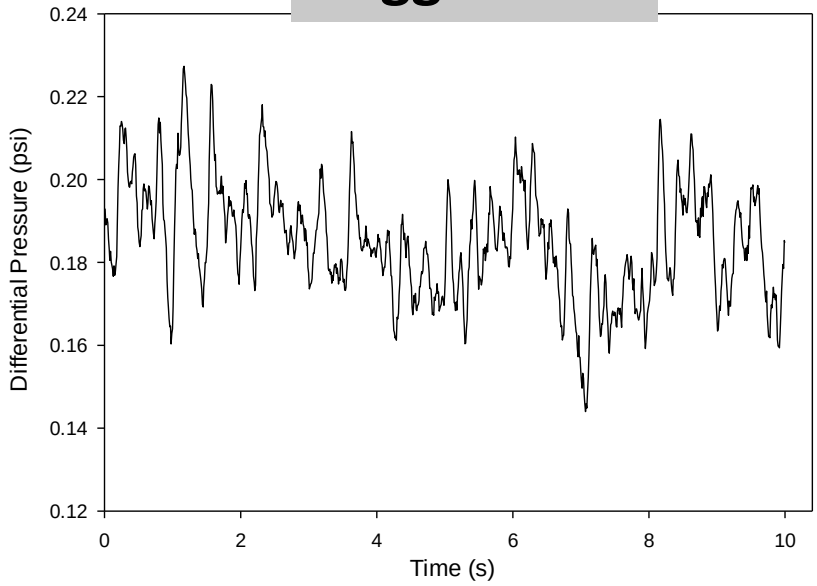


Detection of bogging with bed pressure gradient fluctuations

Dry bed



Bogged bed



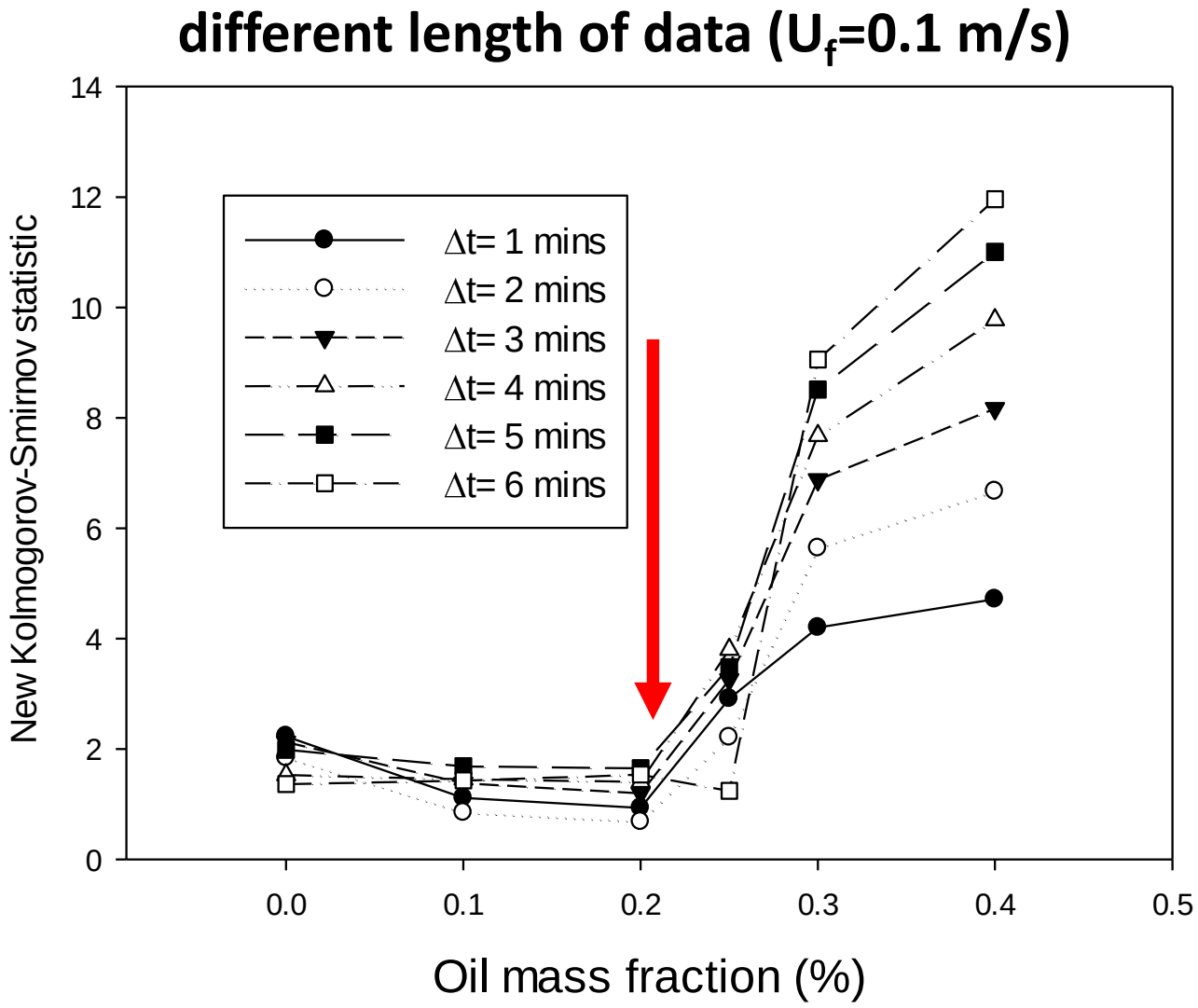
Differential pressure data measured between two vertically separated pressure taps for U_f = 0.1 m/s

Detection of bogging with bed pressure gradient fluctuations

- **Daubechies 4 wavelet transform of pressure signal**
- **Root mean square d_i of the wavelet coefficients for each octave i**
- **Kolmogorov-Smirnov statistic to compare with dry bed:**

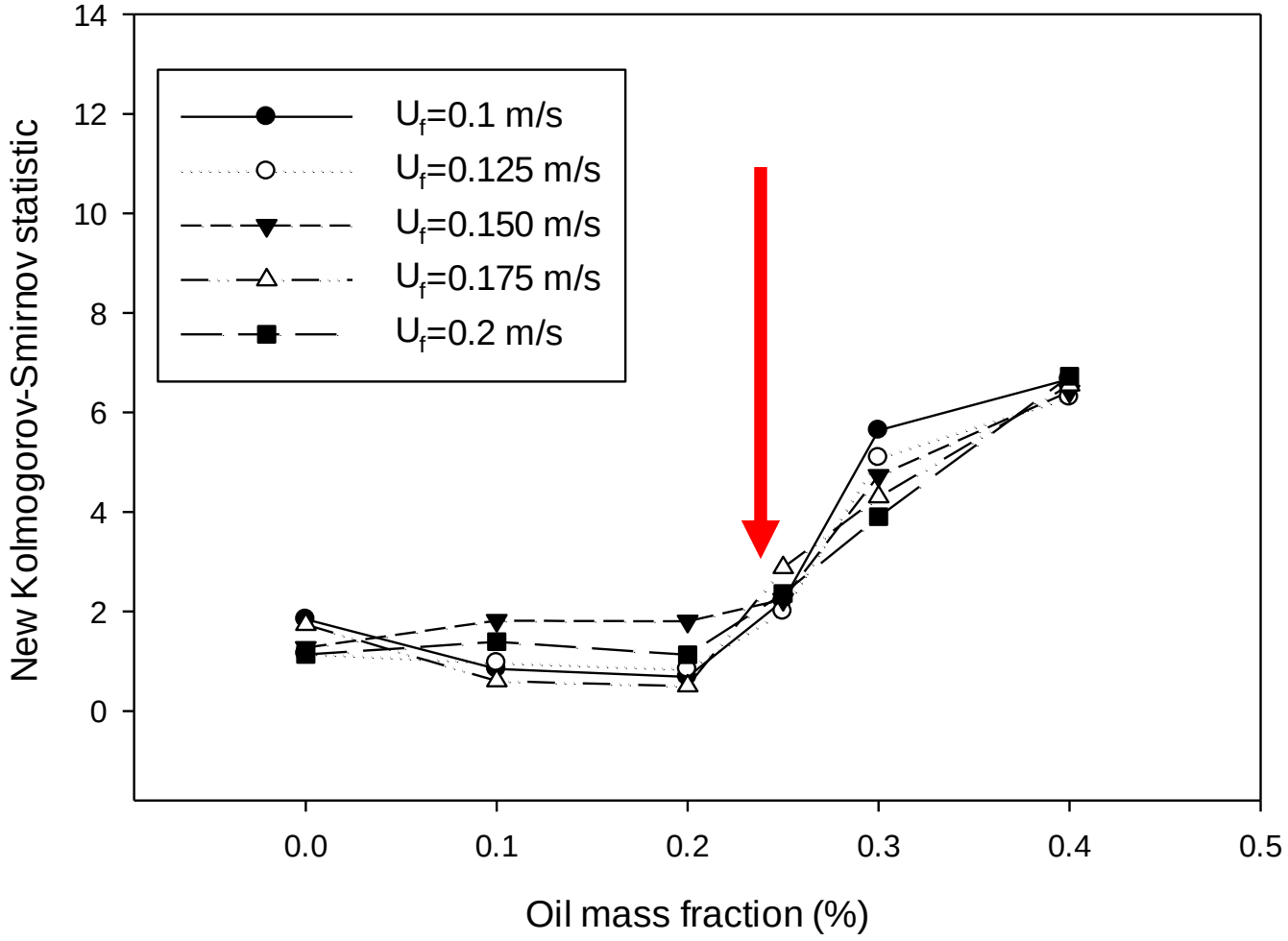
$$B = KS(\prod_{i=1}^{nw} d_i^{\gamma_i})$$

Detection of bogging with bed pressure gradient fluctuations

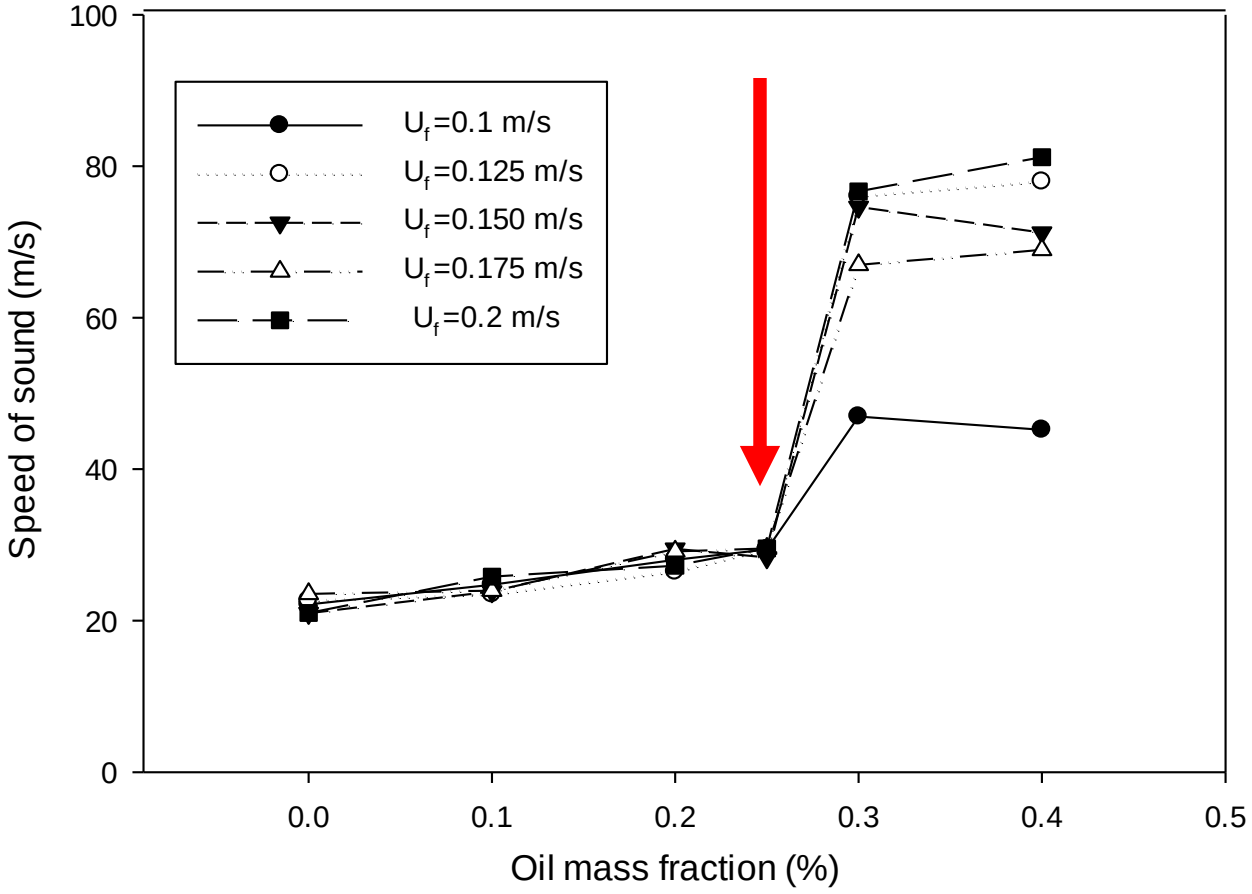


Detection of bogging with bed pressure gradient fluctuations

Using only 2 minutes of data (U_f=0.1 m/s)



Effect of bogging on speed of sound through the bed



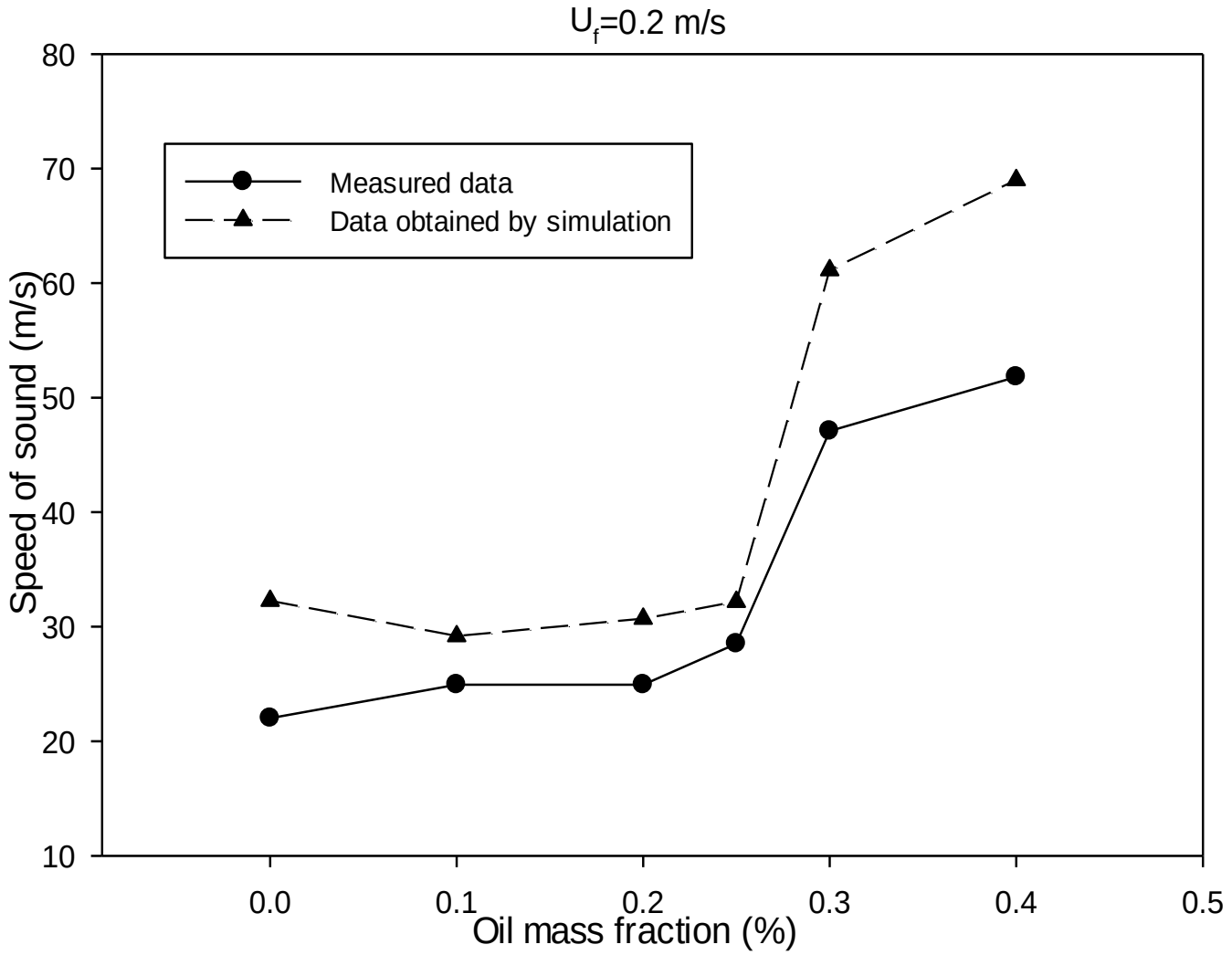
Effect of bogging on speed of sound through the bed

Methods to simulate sound transmission through the fluidized bed:

- **Bubble properties:**
  - **affected by bogging**
  - **affect sound transmission**

- **Propagation of sound in the bed was modelled with Comsol**

Effect of bogging on speed of sound through the bed



Conclusions

- **Bogging greatly affects liquid distribution in a fluidized bed**
- **Bogging affects bubble properties**
- **New successful methods to detect bogging:**
  - **A new bogging index based on pressure fluctuations**
  - **Measured speed of sound in a fluidized bed**
    - **Confirmed with a theoretical model**

Acknowledgements

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