华北电力大学
NORTH CHINA ELECTRIC POWER UNIVERSITY

多相流及燃烧过程检测技术中心

Experimental investigations into the charge distribution and particle velocity characteristics in the bubbling fluidized bed

Wenbiao Zhang

2019-05-29

AIChE The Global Home of Chemical Engineers

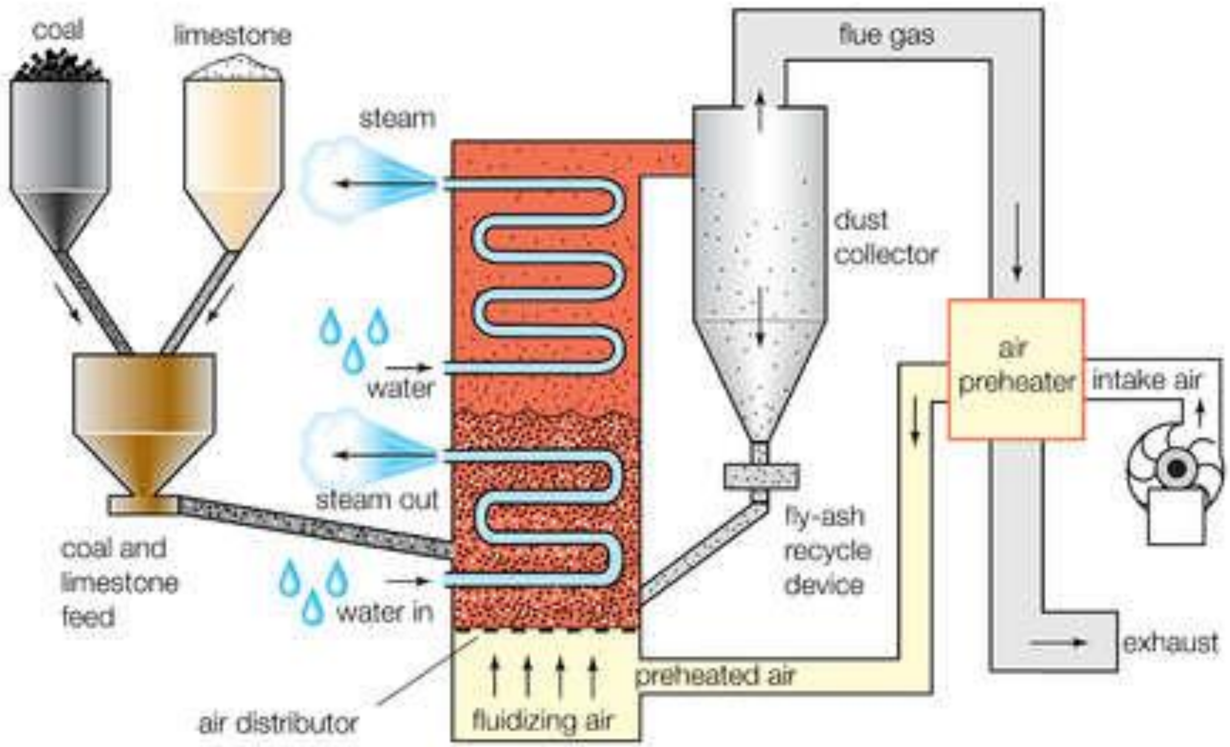
FLUIDIZATION XVI
May 26 - 31, 2019 | Guilin Shangri-La Hotel | Guilin, China

CONTENTS

- Introduction
- Wire-mesh sensors
- Experimental setup
- Results and discussion
- Conclusions

Introduction

- Fluidized beds are widely applied in a range of industries, in particular, power industry.



Schematic diagram of a typical fluidized-bed combustion boiler

Introduction

- In order to maintain the efficient operation of the process, the flow parameters in the bed should be monitored.
- Several techniques have been proposed for the measurement of the flow parameters in a fluidized bed, such as direct visualization, tomography, optical probes, capacitance probes, acoustic measurements and pressure measurements.
- Electrification is inevitable in the fluidized bed and charge distribution in the bed should be monitored.
- Wire-mesh electrostatic sensor arrays are introduced to measure the charge distribution and flow parameters of solid particles in a bubbling fluidized bed.

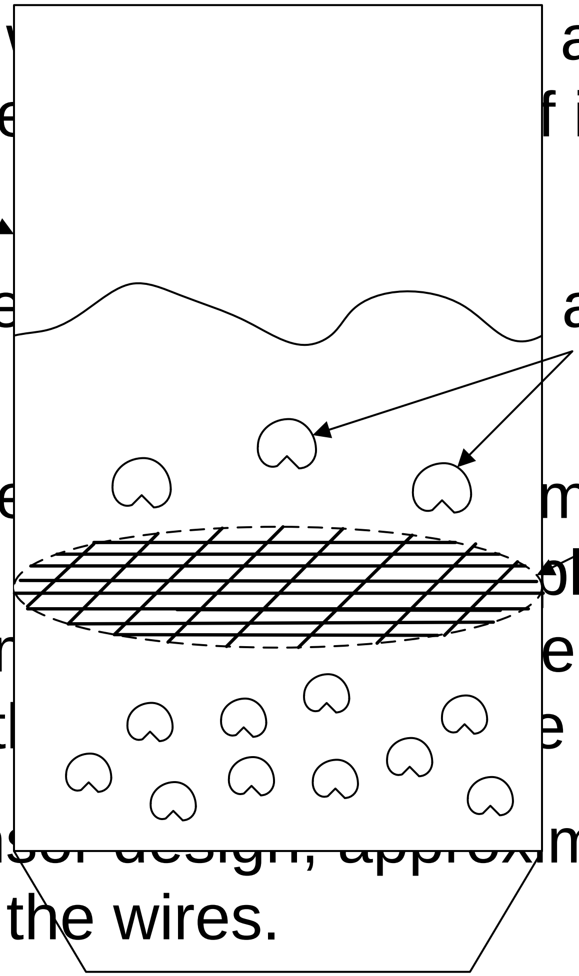
Introduction

Comparison of the existing methods for particle charge measurement

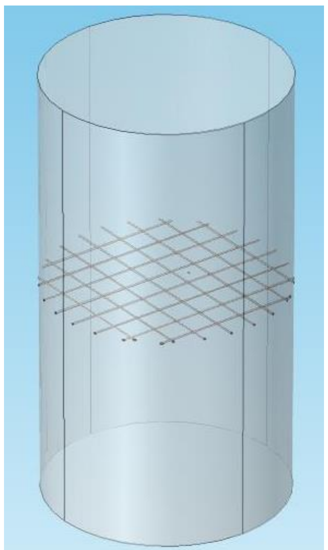
Methods	Sampling requirement	Intrusiveness	Sensitivity distribution	Measurement results
Faraday cups	Sampling of particles is required, charge generation and dispassion during the process may influence the result.	Intrusive	Sensitivity to the particles inside the cup	Electrostatic charge on the samples
Intrusive probes	Not required	Intrusive and the blockage depends on the size and the number of the electrodes	Only sensitive to the particles near the probes	Charge on the particles near the probe
Electrostatic tomography	Not required	Non-intrusive	Sensitivity distribution is not uniform, especially in the central area of the pipe	Reconstructed charge distribution may not represent the true distribution due to non-uniform sensitivity.
Wire-mesh electrostatic sensors	Not required	Intrusive and the blockage depends on the size and the number of the electrodes	Higher and more uniform sensitivity distribution	Cross-sectional charge distribution

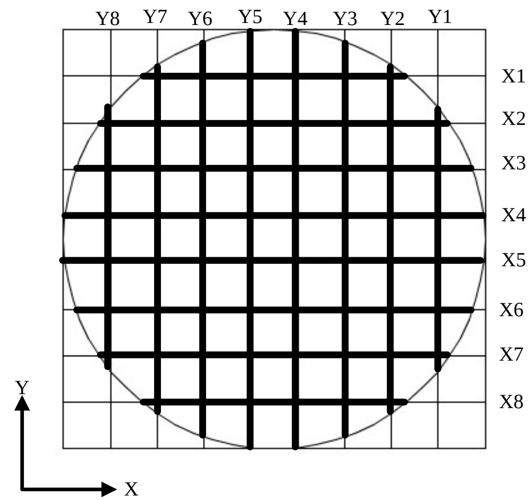
Wire-mesh sensors

- The electrodes of w are made up from two mutually perpe f insulated wires with a diameter of
- In each strand, the an even spacing of 20 mm.
- The wires in the se m stainless steel with a diameter of plastic tubes, with thickness of 0.25 n e direct charge transfer between t e electrodes.
- In the present sens mately 14% of the bed is blocked by the wires.



Sensing characteristics of wire-mesh sensors



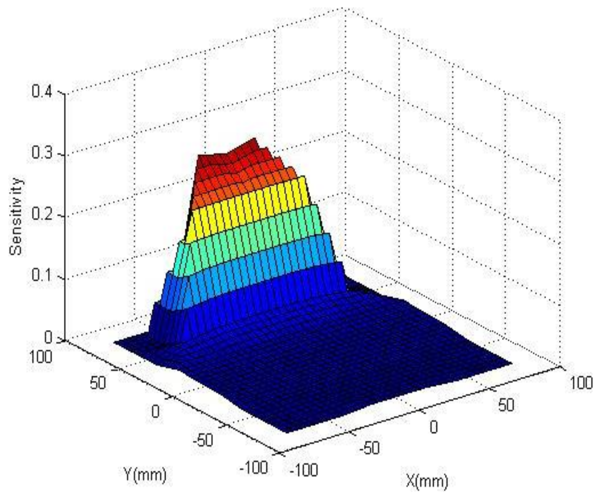


(a) FEM model

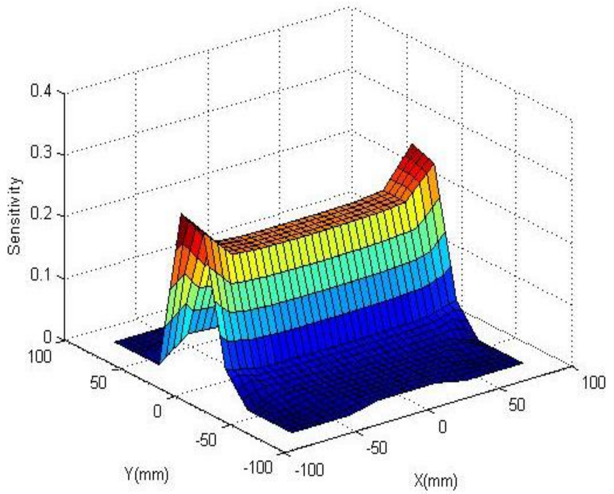
(b) Cross section of the model

Finite element modeling of the wire-mesh electrostatic sensors

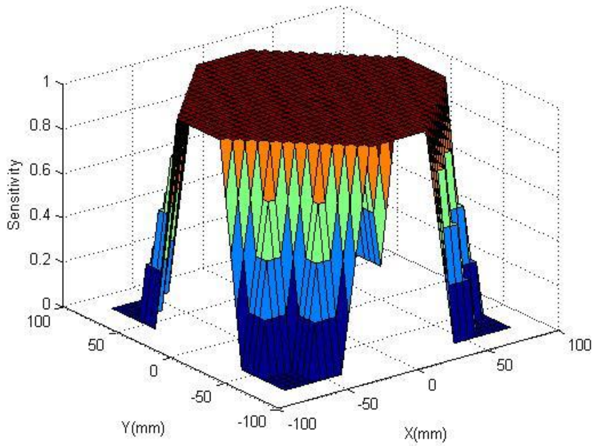
Sensitivity distribution of wire-mesh electrodes



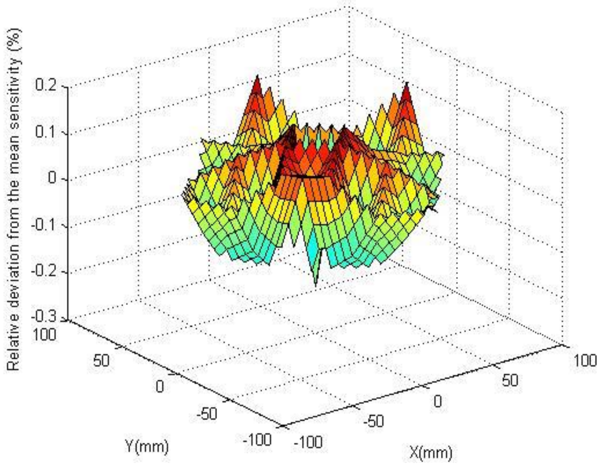
Sensitivity distribution of electrode 1



Sensitivity distribution of electrode 4



Sensitivity distribution of the whole sensor

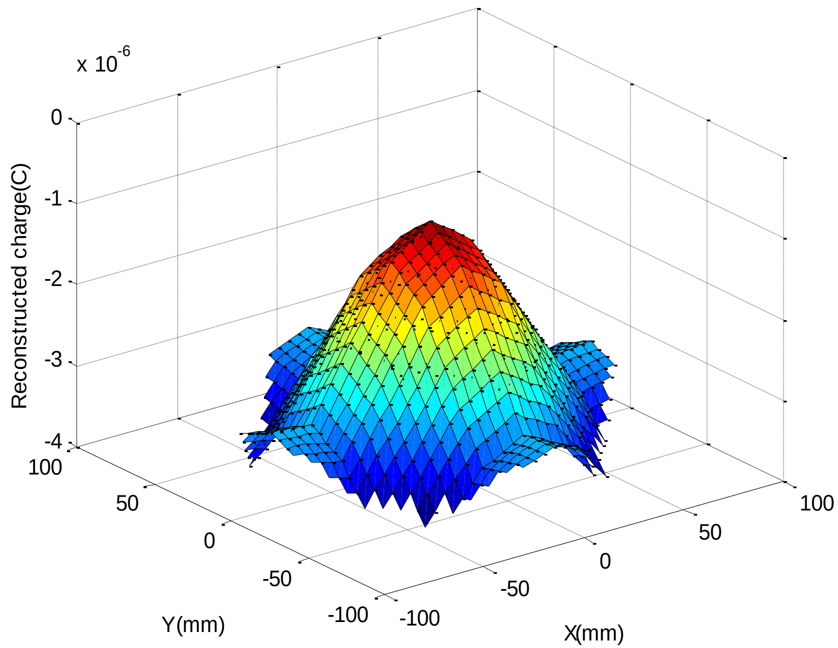


Relative deviation from the mean sensitivity

Charge distribution reconstruction

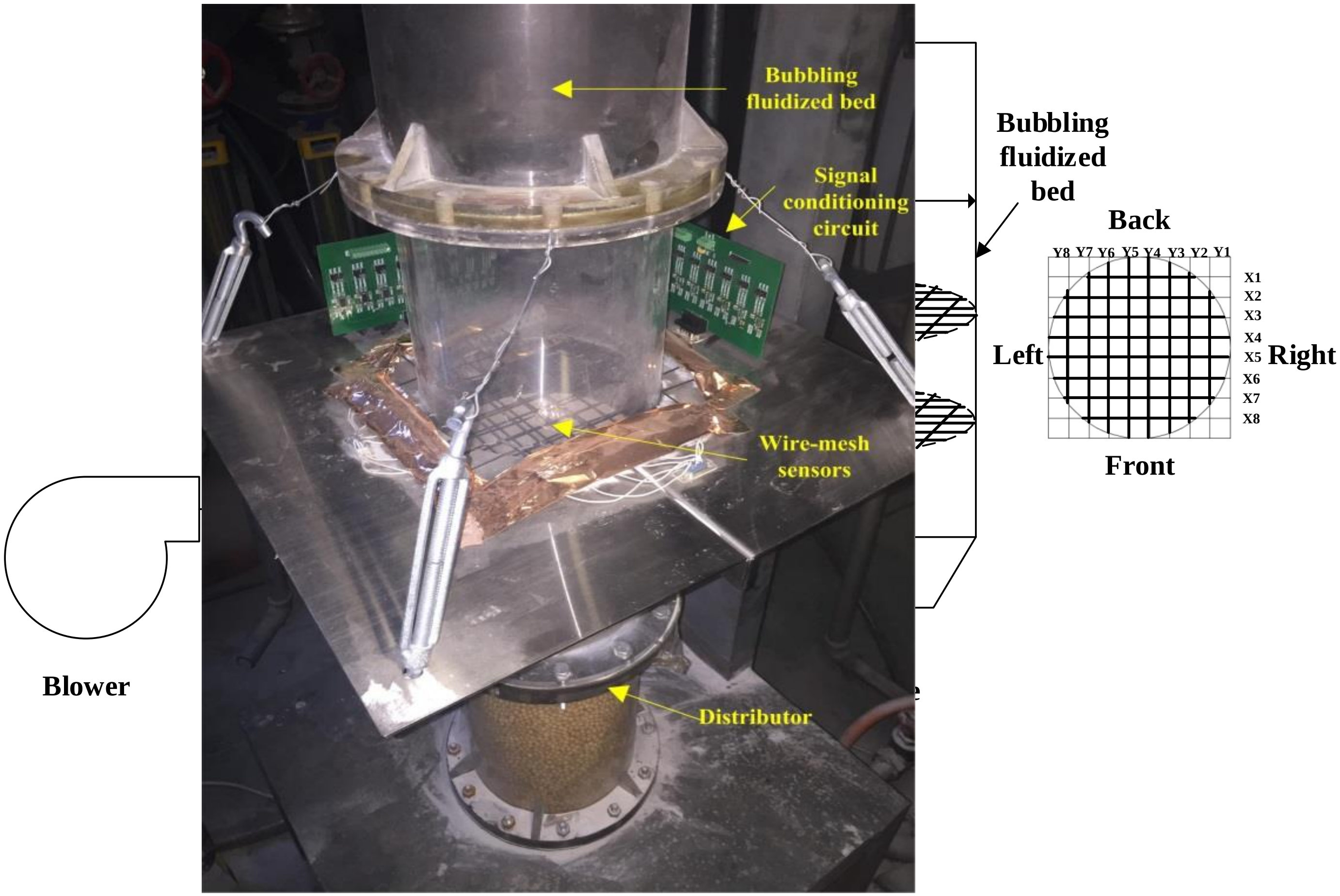
- If the induced charge on each electrode is available, the charge distribution in the cross section can be reconstructed.

$$q_{rec}(x, y) = \frac{1}{16}\sum_{i=1}^{16}\frac{q_i}{S_i(x, y)}$$



Reconstructed charge distribution due to a charged particle in the center of the wire-mesh sensors

Experimental setup

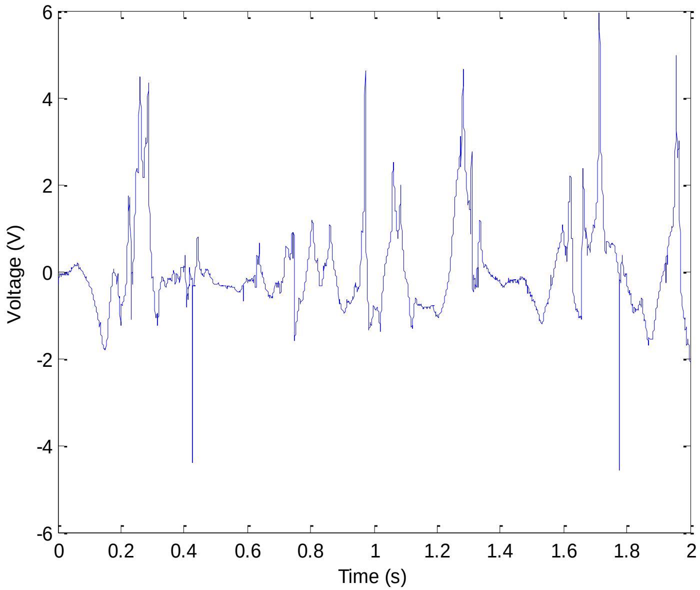


Solid particles: sand
True density: 2500 kg/m^3
Particle size: 150 μm to 200 μm

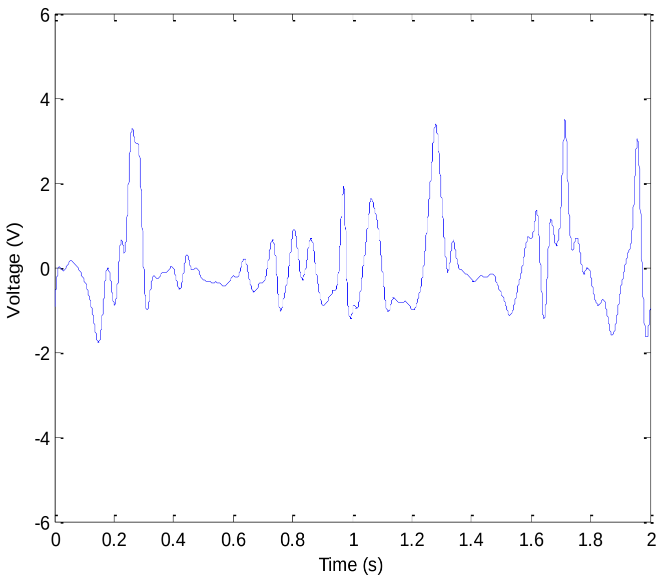
Experimental setup of the bubbling fluidized bed

Results and discussion

Signal processing



(a) Original signal

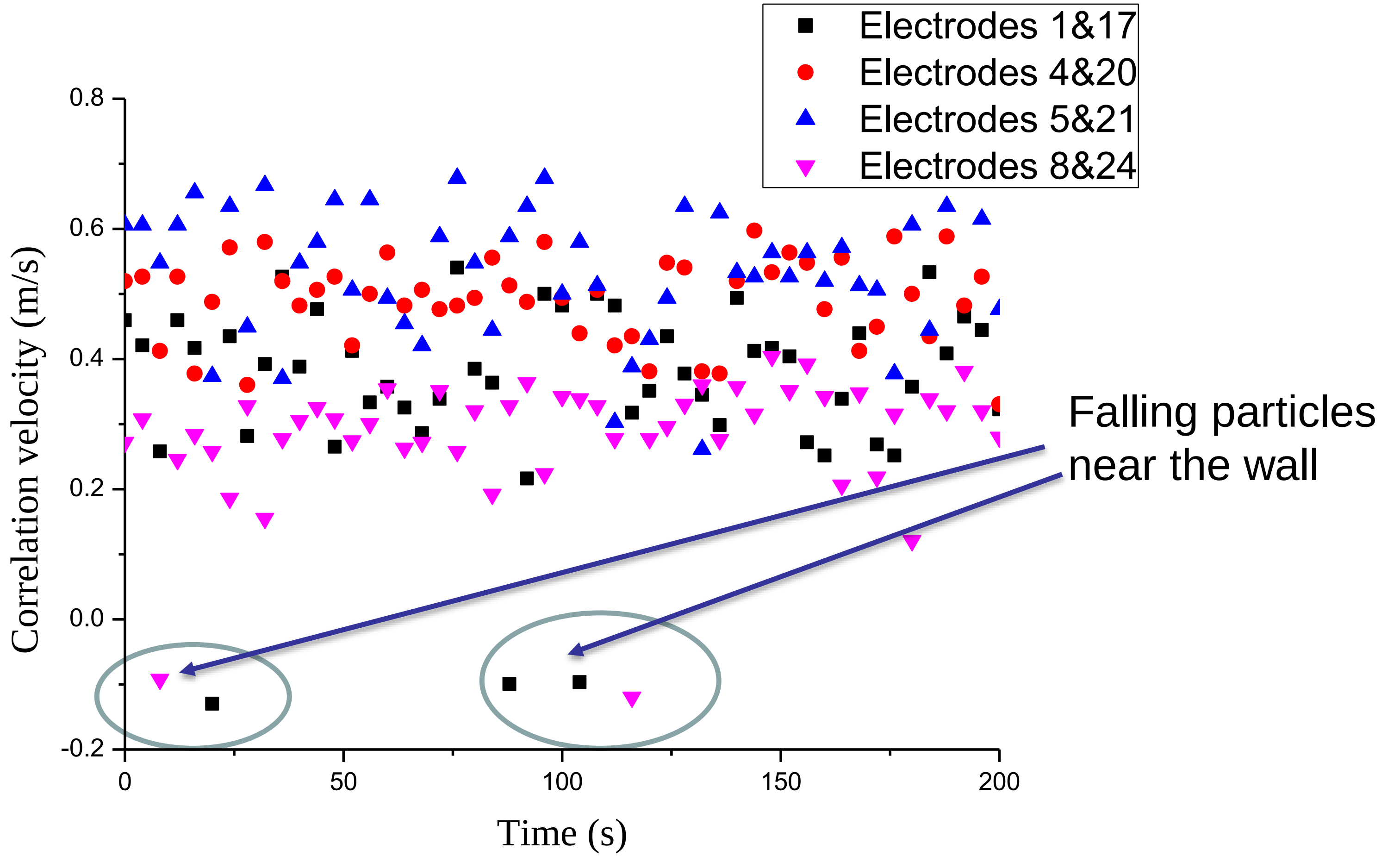


(b) Filtered signal

A typical electrostatic signal from the wire-mesh electrostatic sensors

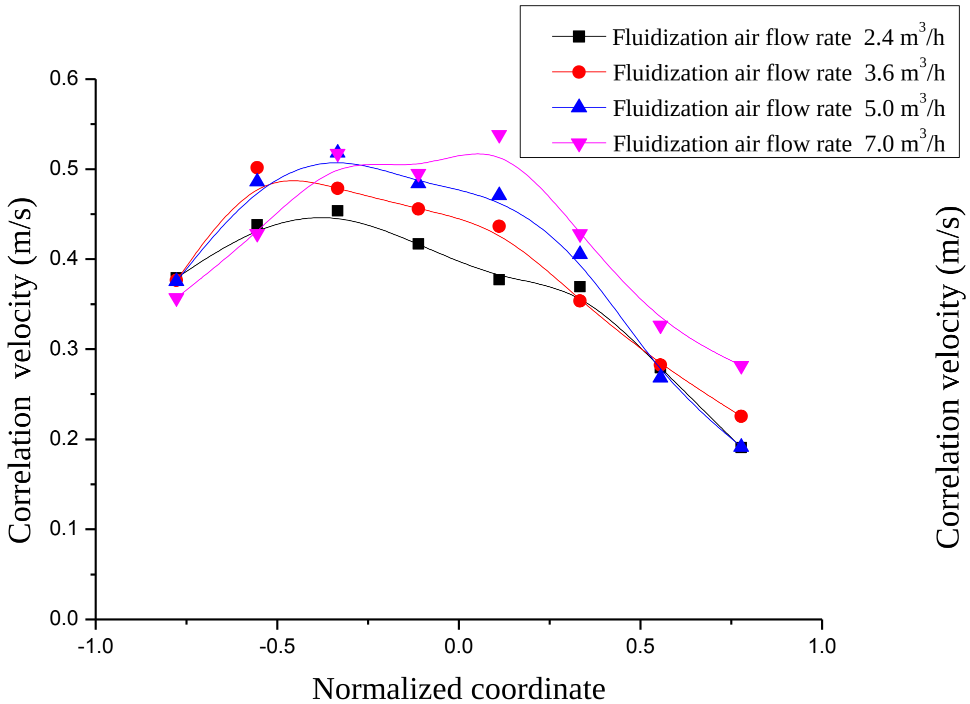
Filtered by Daubechies wavelet of order four

Results and discussion

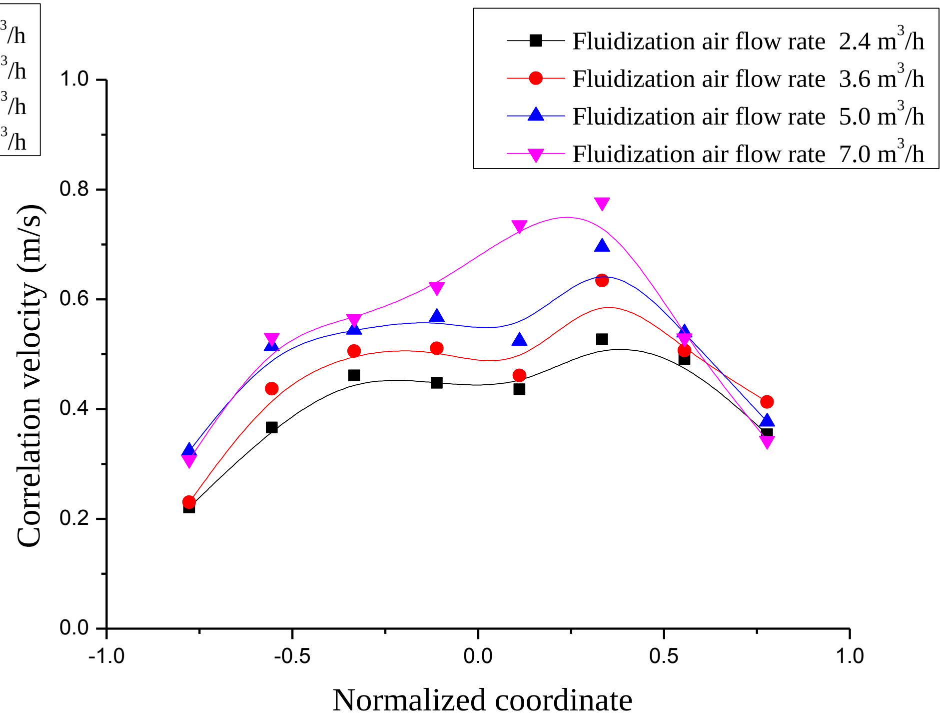


Correlation velocities from the electrodes near the wall and in the middle of the bed along the FB direction under the fluidization air flow rate of 7 m^3/h

Results and discussion



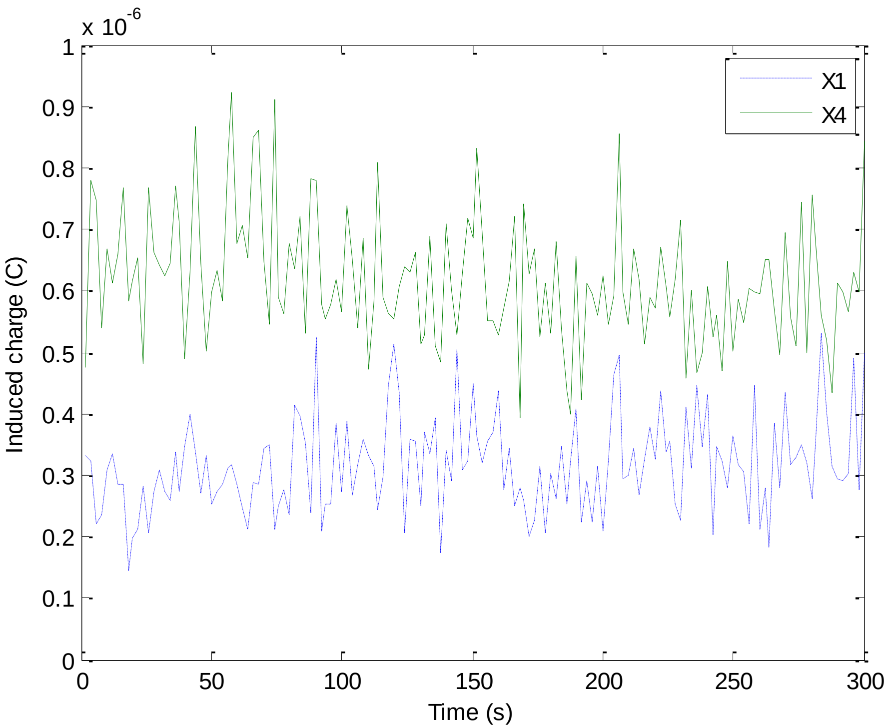
(a) FB direction

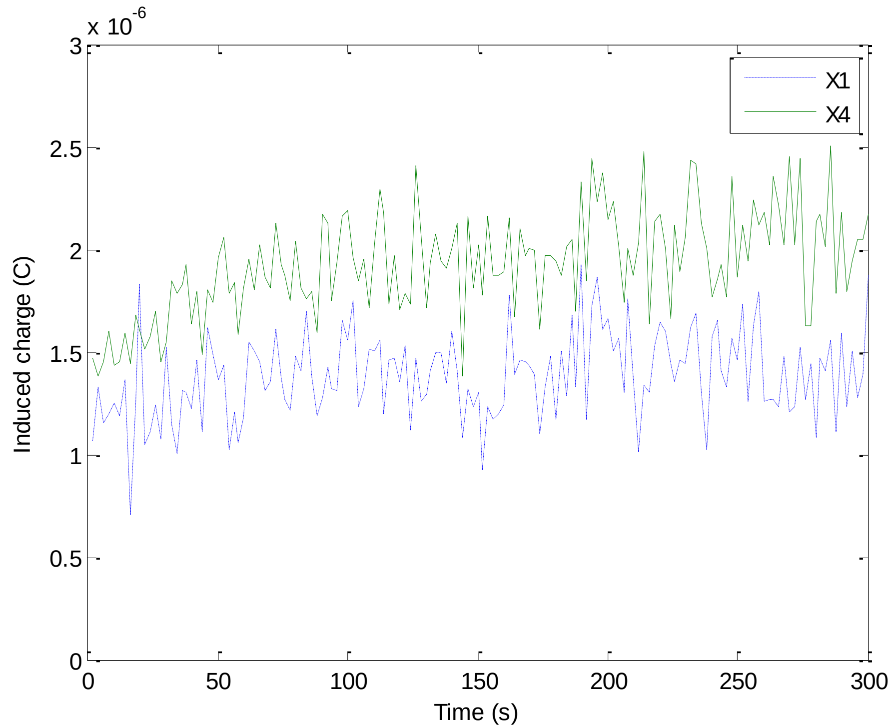


(b) LR direction

Solids velocity distributions of FB and LR directions under different fluidization air flow rates

Results and discussion



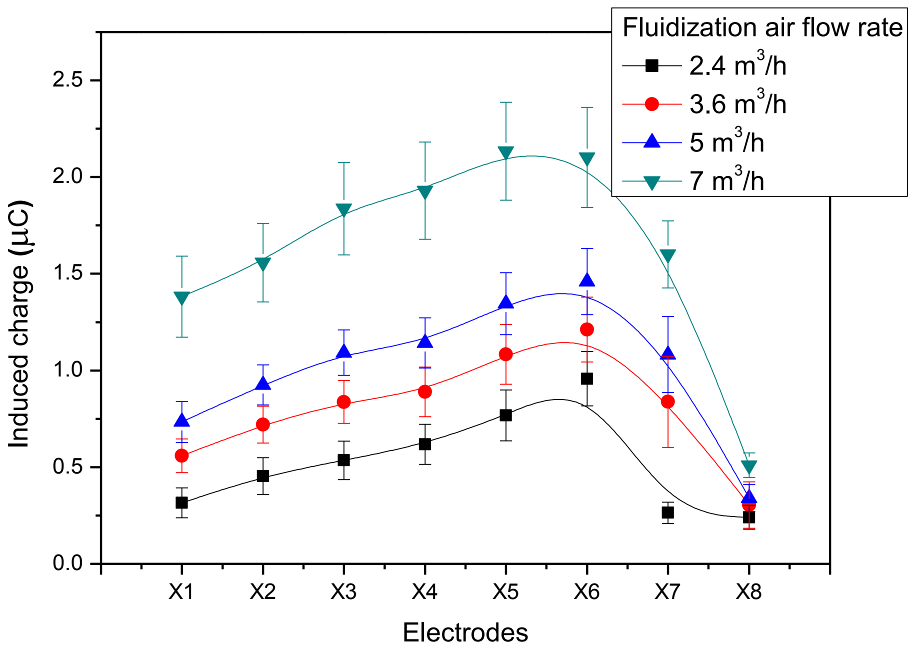


(a) Fluidization air flow rate 2.4 m^3/h (b) Fluidization air flow rate 7 m^3/h

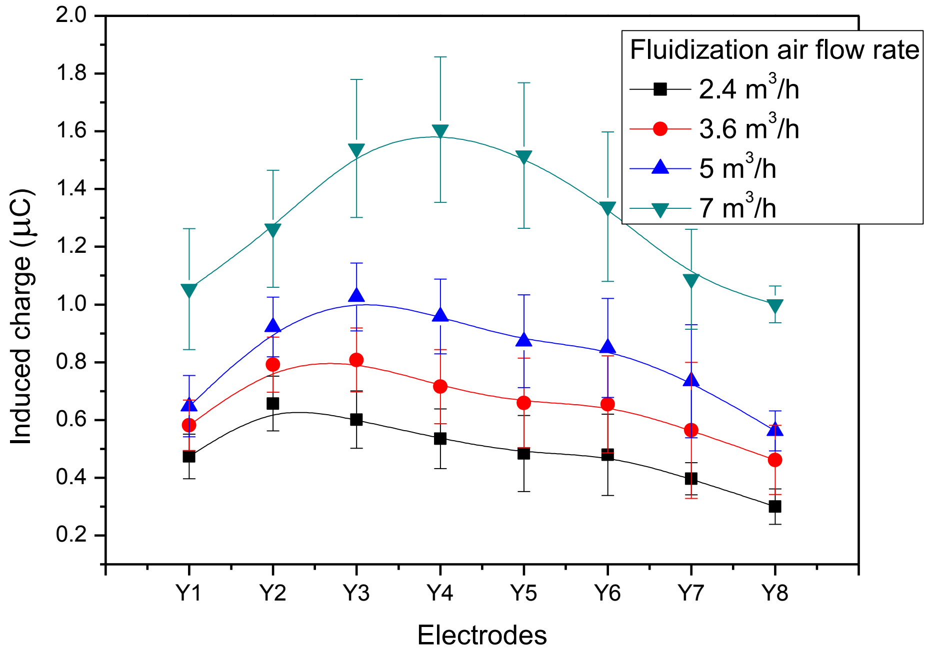
Induced charges on electrodes X1 and X4 in the dense phase region

The average induced charge on electrode X4 is higher than that on electrode X1 under the same fluidization air flow rate

Results and discussion



(a) Electrodes X1 to X8

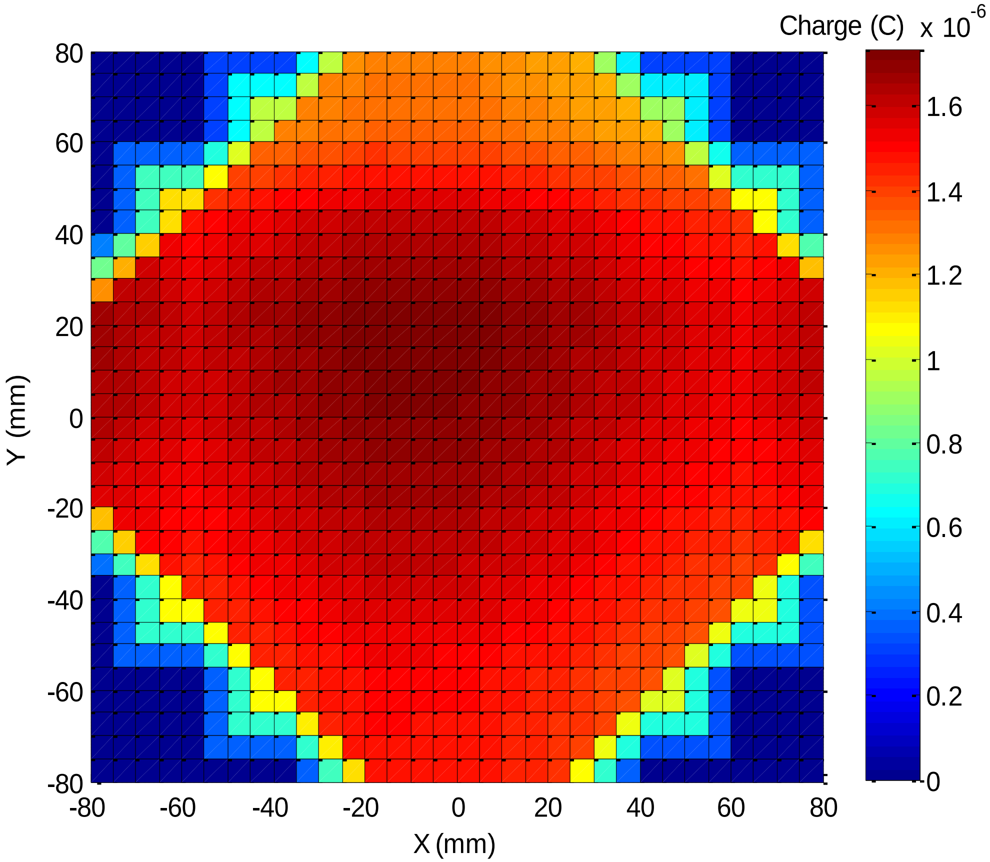


(b) Electrodes Y1 to Y8

Time averaged and corresponding standard deviations of induced charges on different electrodes in the dense phase region

The standard deviation of the induced charge on electrode X4 is higher than that on electrode X1. In addition, the standard deviations of induced charges on electrodes X1 and X4 increase with the fluidization air flow rate.

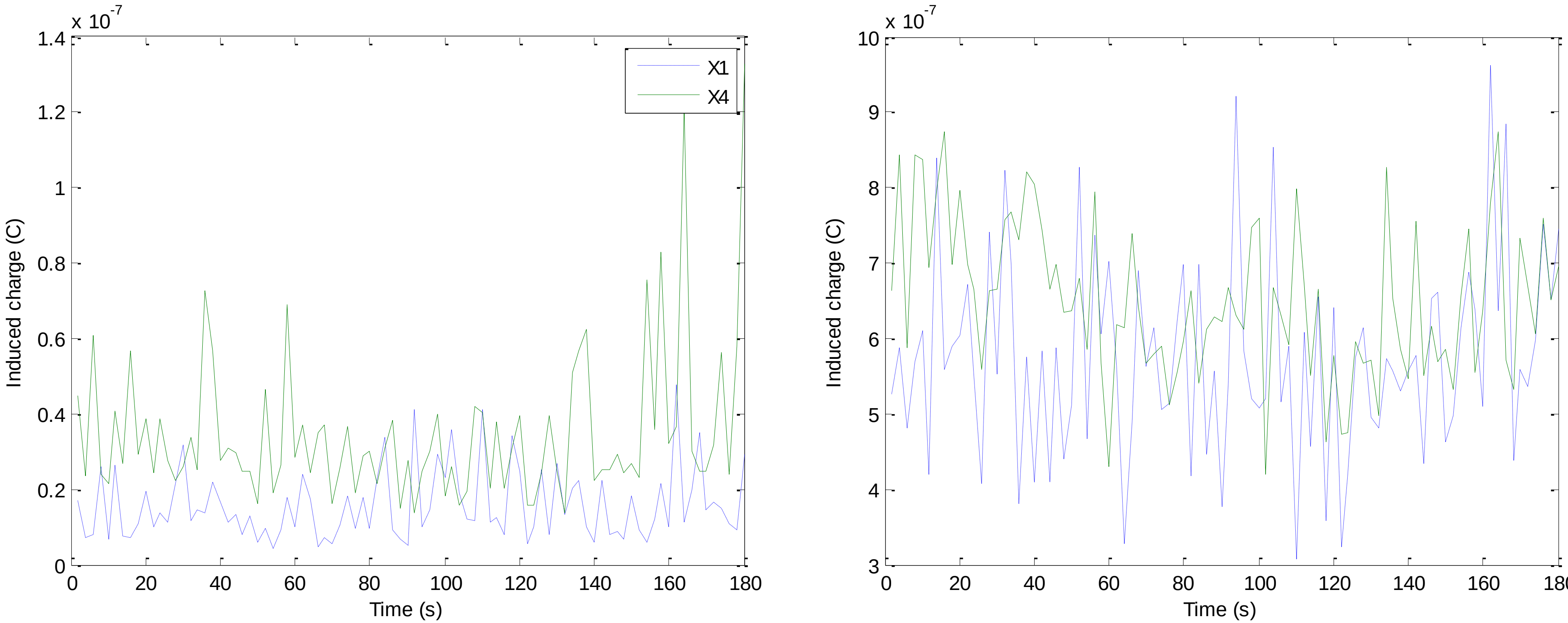
Results and discussion



The charge distribution in the cross section of the dense phase region is relatively uniform.

Reconstructed charge distribution in the dense phase region for fluidization air flow rate of 7 m^3/h

Results and discussion

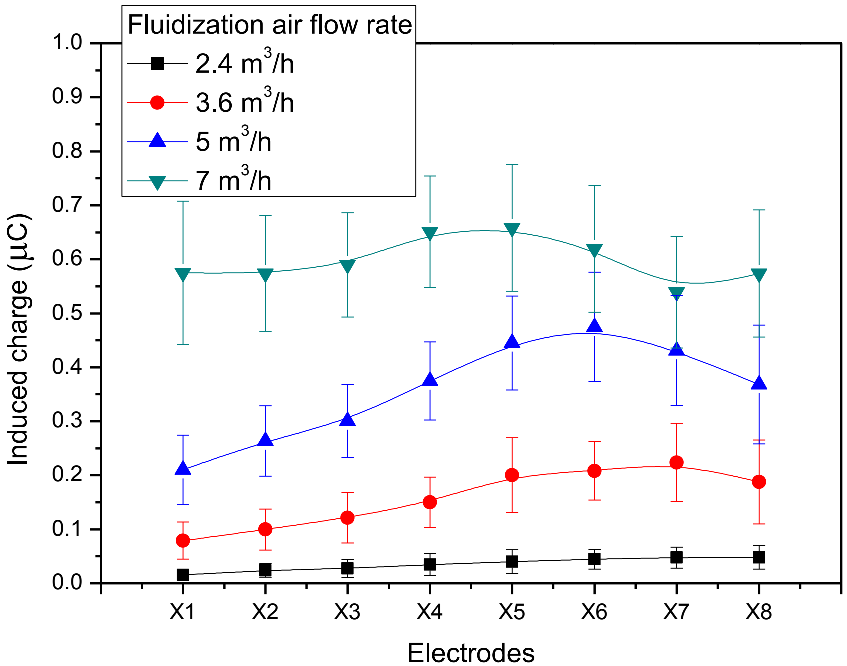


(a) Fluidization air flow rate 2.4 m^3/h (b) Fluidization air flow rate 7 m^3/h

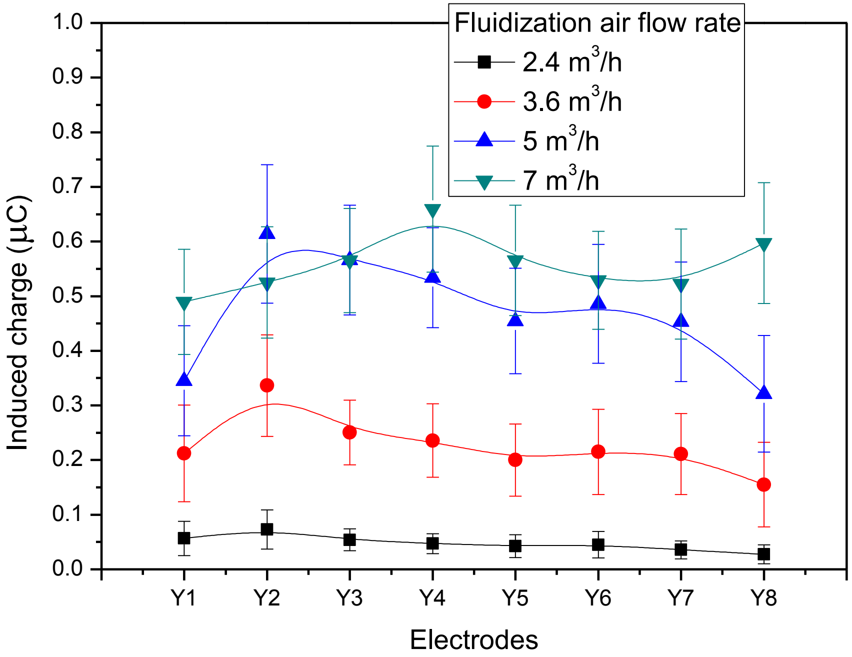
Induced charges on electrodes X1 and X4 in the freeboard region

The induced charge on each electrode for the same air flow rate is smaller due to lower concentration of particles in this region

Results and discussion



(a) Electrodes X1 to X8

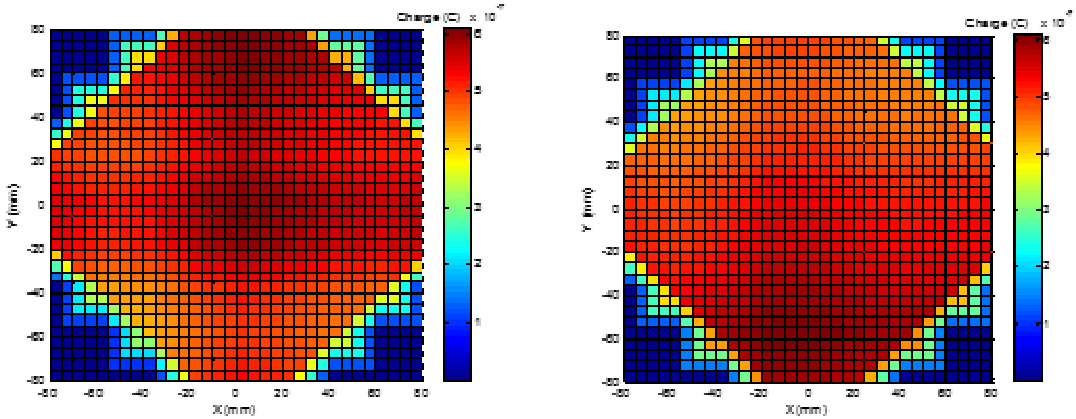


(b) Electrodes Y1 to Y8

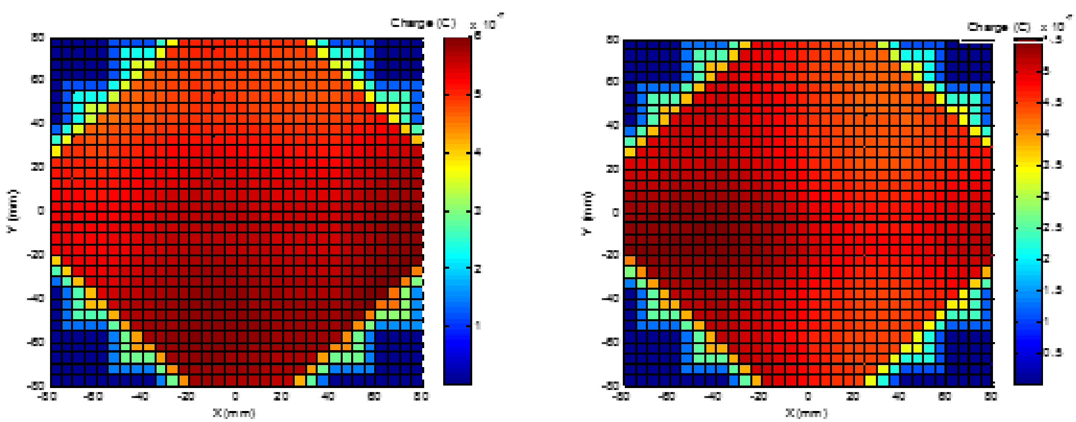
Time averaged and corresponding standard deviations of induced charges on different electrodes in the freeboard region

Because of the highly turbulent solids flow behavior in the freeboard region, the standard deviation of the induced charge on each electrode is higher.

Results and discussion



(a) at 40 second (b) at 80 second



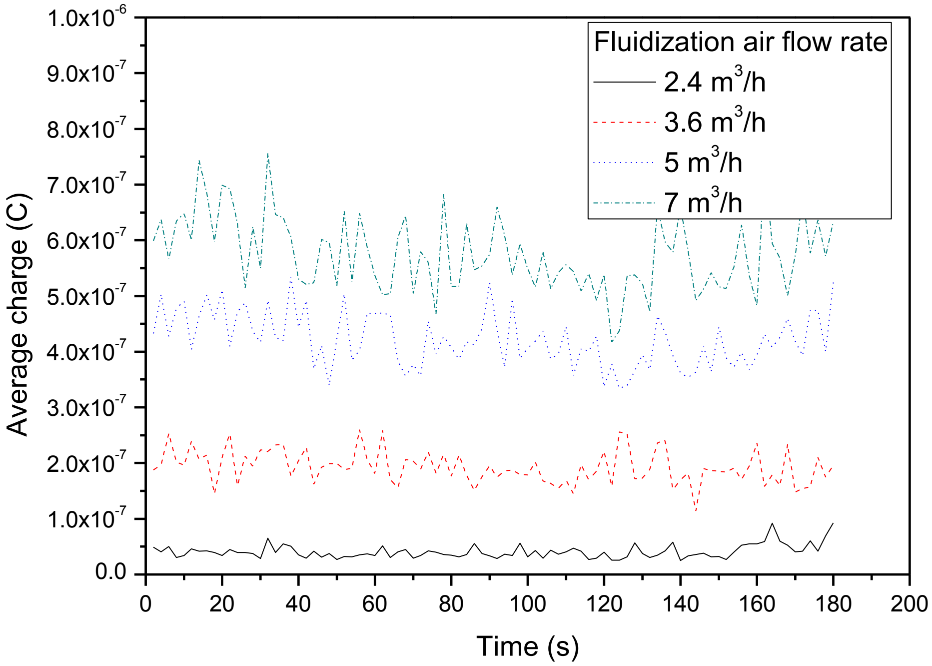
(c) at 120 second (b) at 160 second

The charge distribution in the cross section are strongly influenced by the turbulent flow behavior.

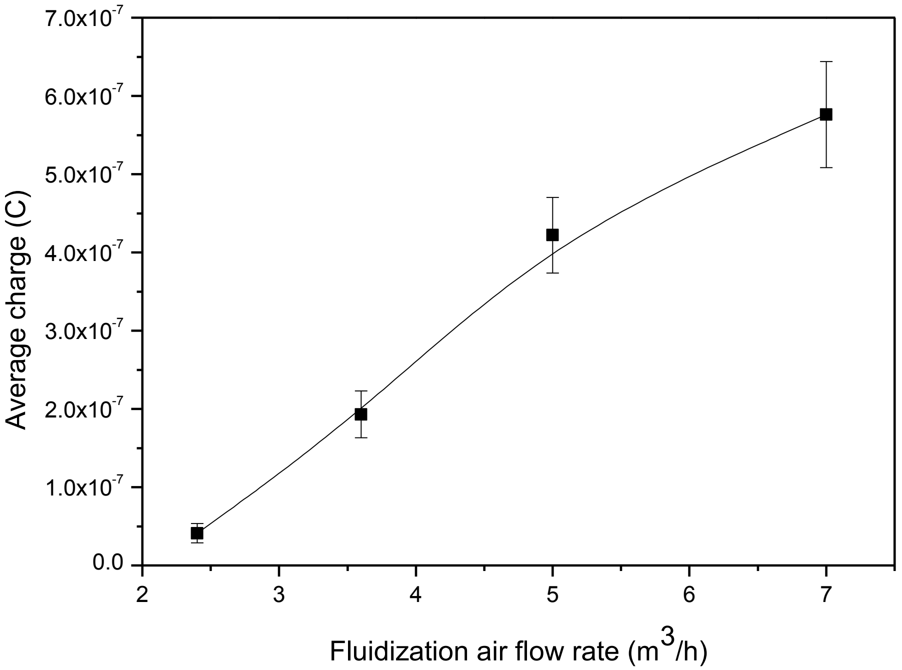
Reconstructed charge distribution in the freeboard region for fluidization air flow rate of 7 m^3/h

NORTH CHINA ELECTRIC POWER UNIVERSITY

Results and discussion



Average charges of the cross section for different fluidization air flow rates in the freeboard region



Time averaged and corresponding standard deviations of the average charges of the cross section

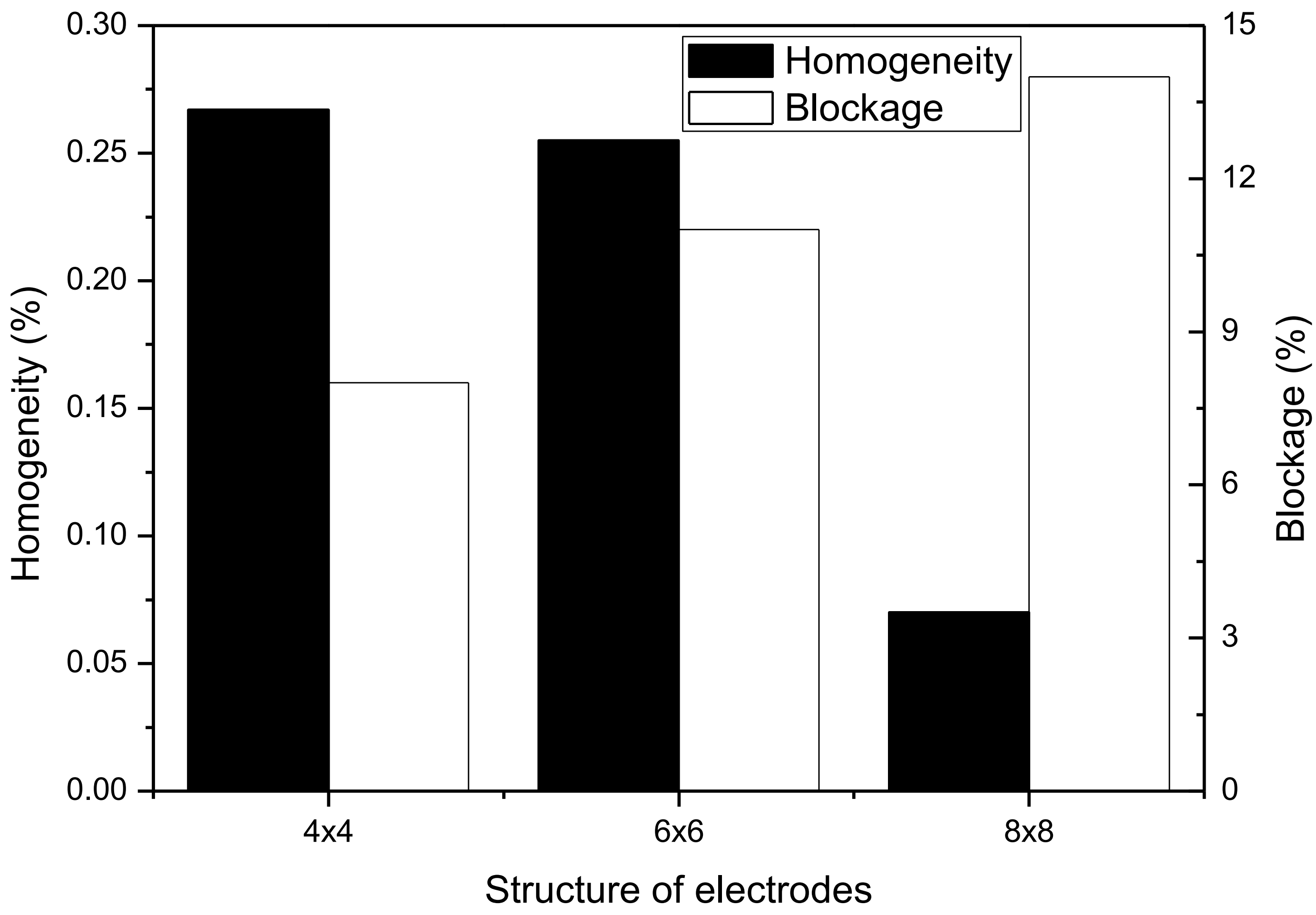
Conclusion

- The wire-mesh electrodes can obtain a higher and more uniform sensitivity distribution.
- It can measure the charge distribution and velocity distribution of solid particles in the bed.
- In the dense phase region, the induced charge on the electrode in the center of the cross section is higher than that in the near wall region and the charge distribution in the cross section is relatively uniform, with the maximum relative deviation from the mean charge less than 24%.
- In the freeboard region, the induced charges on the electrodes and the charge distribution in the cross section are strongly influenced by the turbulent flow behavior and the charges in different parts of the bed fluctuate over time.

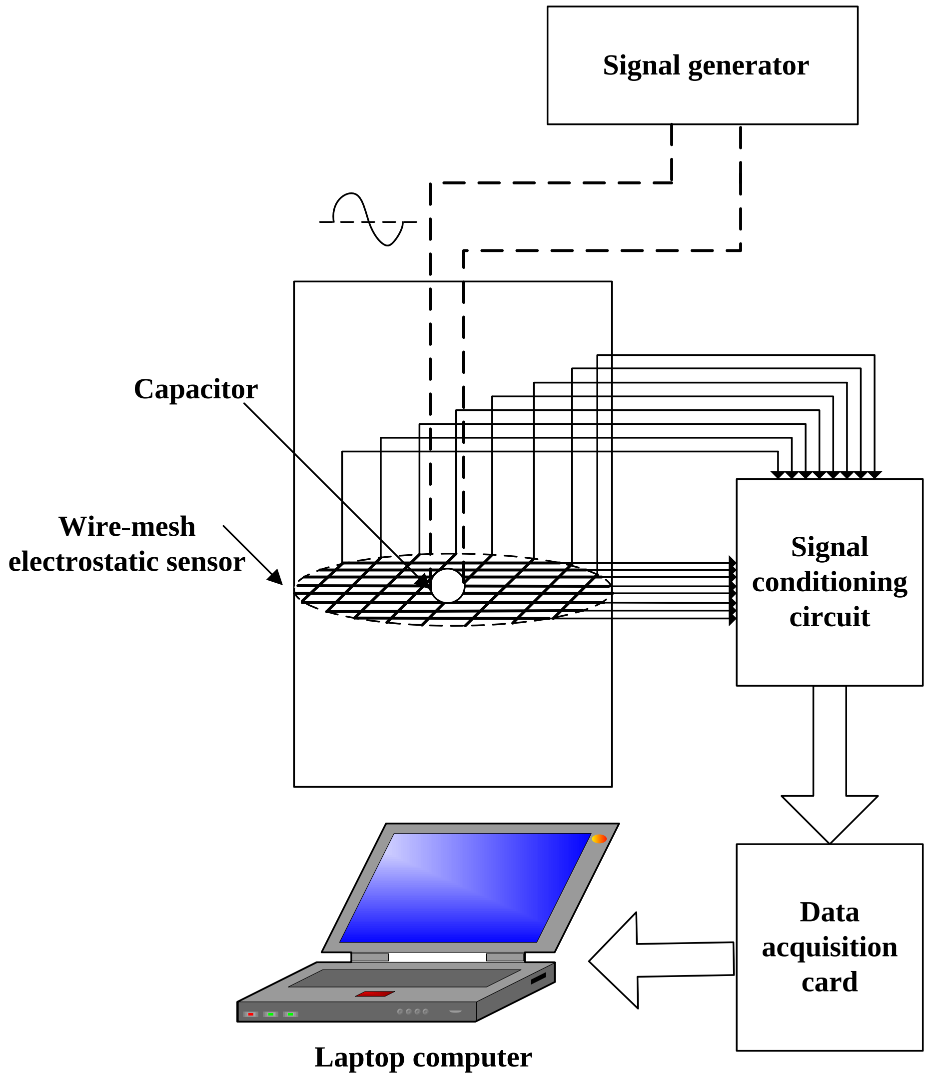
Thank you for your attention!

Corresponding email:
wbzhang@ncepu.edu.cn

National Natural Science Foundation of China (No. 61403138)
Beijing Natural Science Foundation (No. 3162031)



Homogeneity of the sensitivity distribution and the blockage of the wire-mesh sensors for different numbers of electrodes



Experimental set-up of the charge calibration process