X-ray Measurement of Cluster Velocity and Acceleration in the Near Wall Region

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Abstract. Cluster is one of critical issues in the gas-solid two-phase flow study. Its formation, dissolution and evolution has significant effect on the mass and heat transfer of the reactor. The widely adpoted measuring techniques, such as optical fiber and capacitance probe, generally involve the introduction of an intrusive probe into the reactor, which will disturb the flow field and thereby greatly decrease the reliability of measurement result. An X-ray based technique for the measurement of clusters in the near wall region was proposed in this study. By analyzing the one dimensional projection data, the information of voidage, size, velocity and acceleration of the cluster can be obtained simultaneously. Compared with the optical method, the newly developed technique can provide a trustworthy result non-invasively.

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Introduction

Cluster is one of critical issues in the gas-solid two-phase flow study[1]. Its formation, dissolution and evolution has significant effect on the mass and heat transfer of the reactor. The widely adopted cluster measurement techniques, such as optical fiber and capacitance probe, generally involve the introduction of an intrusive probe into the reactor, which will disturb the flow field and thereby greatly decrease the reliability of measurement result. An X-ray based technique[2] for the measurement of clusters in the near wall region was proposed in this study. By analyzing the one dimensional projection data, the information of voidage, size, velocity and acceleration of the cluster can be obtained simultaneously.

Experimental

The X-ray scanning system consists of a 100 kV/2.25 kW constant potential X-ray source (Yxlon) with an emergent beam angle of 40° and two focal spot sizes of 1.0 and 3.0 mm respectively, and an equally spaced detector array with 1536 sensitive elements (Gd screen as scintillator material), pixel width and height being 0.3 and 0.6 mm respectively, integration time ranging between 0.67 to 30 ms, and A/D resolution of 14 bits. Both components are mounted on a specially designed gantry around the circulating fluidized bed (CFB) reactor, as Fig. 1 shows. In this study, the working voltage and current for X-ray source is 100kVp and 2.1mA respectively, and the sampling frequency for the detector is 50 Hz.

The CFB reactor used in this study has a total height of 12.43m, and an inner diameter of 411 mm.

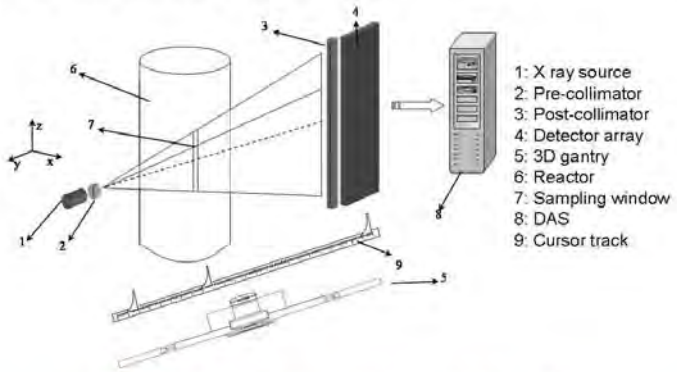

Fig.1 The cluster measurement technique schematic

Results & Discussions

Generally speaking, the solid clusters travel downward along the riser wall, the time series of raw projection data is shown in Fig. 2.

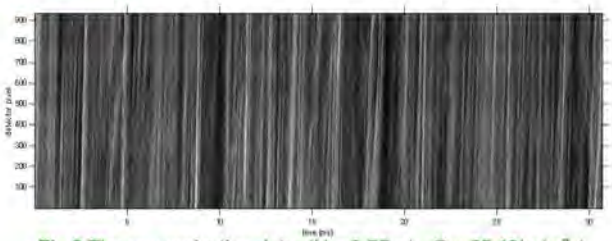

Fig.2 The raw projection data. (Ug=3.57m/s, Gs=65.13kg/m^{2}s)

The space translation can be computed by the cross-correlation analysis as the following equation shows.

$$R(\tau) \overset{\text{def}}{=} (S_1 \star S_2)(t) \overset{\text{def}}{=} \int_{-\infty}^{\infty} S_1^*(\tau)\, S_2(t+\tau)\, d\tau$$

The cluster identification criteria is determined by sensitivity analysis, and in this case, which is 1.4 σ above the mean value, as shown in Fig. 3 (left).

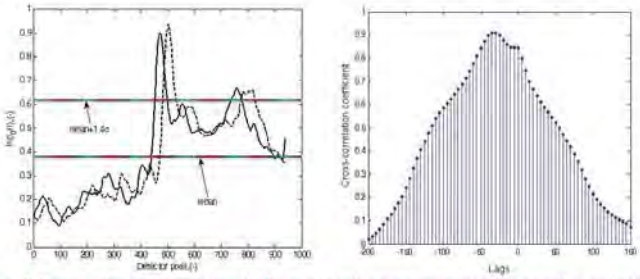

Fig.3 Two adjacent samples (left) and their cross-correlation coefficient (right)

The information of detector spacing and sampling frequency if known, we can compute the cluster velocity series and acceleration after obtaining the cluster space translation data, as shown in Fig. 4.

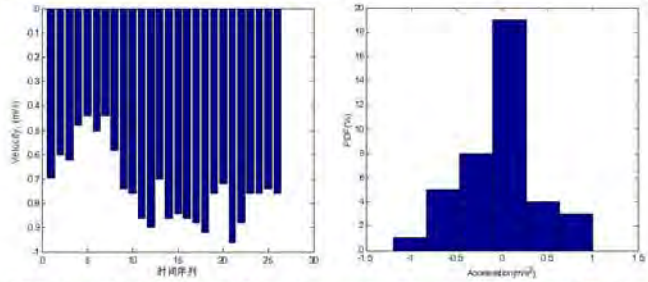

Fig.4 Cluster velocity series (left) and corresponding acceleration distribution (right)

Conclusions

An X-ray based technique was developed for the dynamic measurement of clusters in the near wall region of gas-solid two phase reactor. Compared with the intrusive method widely used nowadays, the newly developed technique can provide a trustworthy result non-invasively.

[1] Harris A T, Davidson J F, Thorpe R B. The prediction of particle cluster properties in the near wall region of a vertical riser. Powder Technology, 2002, 127:128-143.

[2] Fanyong Meng, Wei Wang, Jinghai Li. A technique for measurement of cluster velocity and acceleration. China patent, CN101876663A

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