VIDEOGRAMETRY IN FLUIDIZED BED REACTORS

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Summary The main task of this research work was to develop and then apply method for evaluation of the homogeneity of the fluidized bed, based on digital image analysis for different types of fluidization, and to compare and correlate the results. Various types of fluidization was recorded with the use of high speed CCD video camera and frame sequences of recorded two-phase flow were put under digital image analysis on the basis of brightness level of the image measurement.

Experiments on identification and evaluation of two-phase gas-solid flow pattern in fluidized bed model apparatuses were carried out. The main task of this research work was to evaluate the homogeneity of the fluidized bed for different types of fluidization in different types of fluidized bed reactors. The dynamics of homogeneity changes have been expressed as change of brightness level value of the image in time and space domain. By the analysis of brightness level of each pixel of each image in the frame sequence, the grey level fluctuation function is drawn (Figure 1). The grey level function is base signal for further analysis in stochastic manner (Figure 2). Functions such as autocorrelation and probability density have been used for that analysis. The experimentation was held in different fluidization columns with transparent walls. Various types of fluidization was examined with the use of high speed CCD video camera.

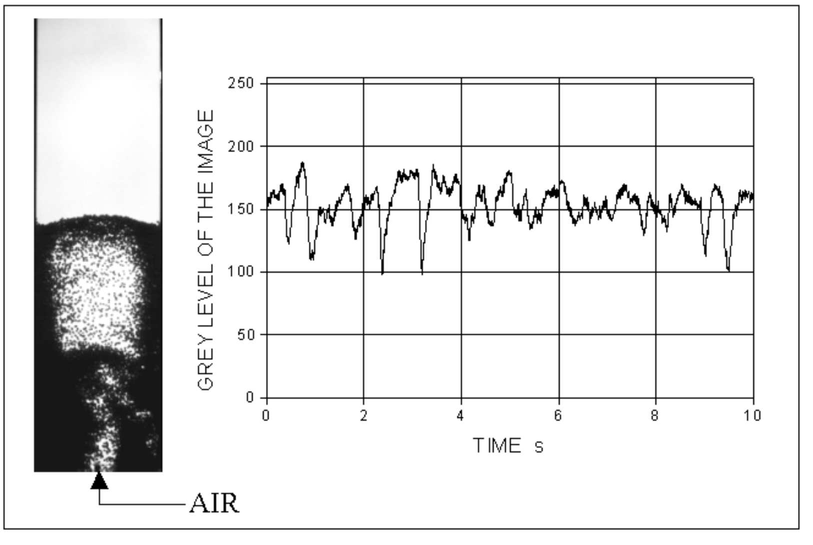

Figure 1. Example image of bubbling fluidization and example graph of grey level of the image fluctuation.

Technology of the fluidization of solid particles with gas stream is known for almost 100 years, but behaviour description of such two-phase mixture still causes problems. This is because of the huge amount of particles, which interacts between themselves, walls and other obstacles inside the reactor. The influence of the geometrical structure of the vessel on the flow pattern intensifies with the increase of the complicity of the flow geometry of the apparatus. Dynamic description of movement of such set of particles requires detailed information about factors responsible for particular two-phase flow structure and needs application of image and stochastic process analysis.

New measurement method for two-phase gas-solid flow, called videogrametry, was carried out. This method allows dynamic space and time analysis of phase concentration distribution inside the fluidization apparatus, on the basis of image analysis of brightness of pixels of the image in specified area. Method was applied for estimation of the vessel structure influence on distribution of phase concentration for different types of fluidization.

Experiment was carried out on three different two-dimensional models of fluidization apparatus with rectangular cross section. First for bubbling fluidization – a chamber with a grill. Second for jet spouted fluidization – chamber with conical section and vertical conveying riser mounted axially inside the vessel. Third for fast fluidization – vertical riser with recirculating solid particles. The subject of investigation was two-phase gas-solid flow structure estimation in dependence of geometry of the fluidization chamber. Void fraction was measured in different places inside the vessel. Solid particles with diameter of 1 to 10 millimetres and density of 1000 kg/m^3 were fluidized with air. Air velocity inside the flow channels was in range of 1,5 to 17,0 m/s. All velocities were calculated for empty vessels.

Visualization of the process was possible due to application of transparent materials for building the apparatus models, and digital video camera for high speed capturing of high resolution images. Used CCD camera is capable of getting up to 1800 frames per second and the resolution of the images is 1024/1024 pixels. These features of the applied video camera enable recording of very fast processes.The values of such parameters as heat, mass and momentum transfers are strongly dependent on hydrodynamic condition of the bed, it causes that the flow pattern of two-phase flow is the criterion of similarity for comparing processes held in different constructed reactors.

There are many various measurement methods for investigation of two-phase flow systems. One of them, worked out by our research team – videogrametry – is an optical method based on analysis of the recorded images of the flow. These images are bitmaps with recorded distribution of solid phase concentration in the form of brightness level distribution. With the use of dynamic image analysis of brightness level of each pixel in every image in the sequence, space and time characteristic of brightness level fluctuation were obtained. Brightness level is also called grey level. Change of grey level is time and space depending function. Brightness level of pixel or image was measured in range of 0 – 255, where 0 means black or 100% solid phase, and 255 means white or 100% gas phase. Results between these boundaries are grey levels. Using simple transposition functions allows calculating the grey level to void fraction. Additional stochastic analysis was made for brightness level functions to get information on the process in frequency domain. Correlation of the results shows that each classified two-phase flow structure has its own and original pattern of the grey level changes. Different types of flow regimes have their own original sets of grey level fluctuation patterns.

On figure 2 there are shown results of stochastic analysis of the grey level fluctuation signals for two types of flow regime. Figure 2A presents three graphs for plug two-phase gas-solid flow. The images grey level fluctuation pattern (top graph). Below there are probability density function (PDF) and autocorrelation function (ACF). In the same manner figure 2B shows result of digital image analysis for turbulent flow regime.

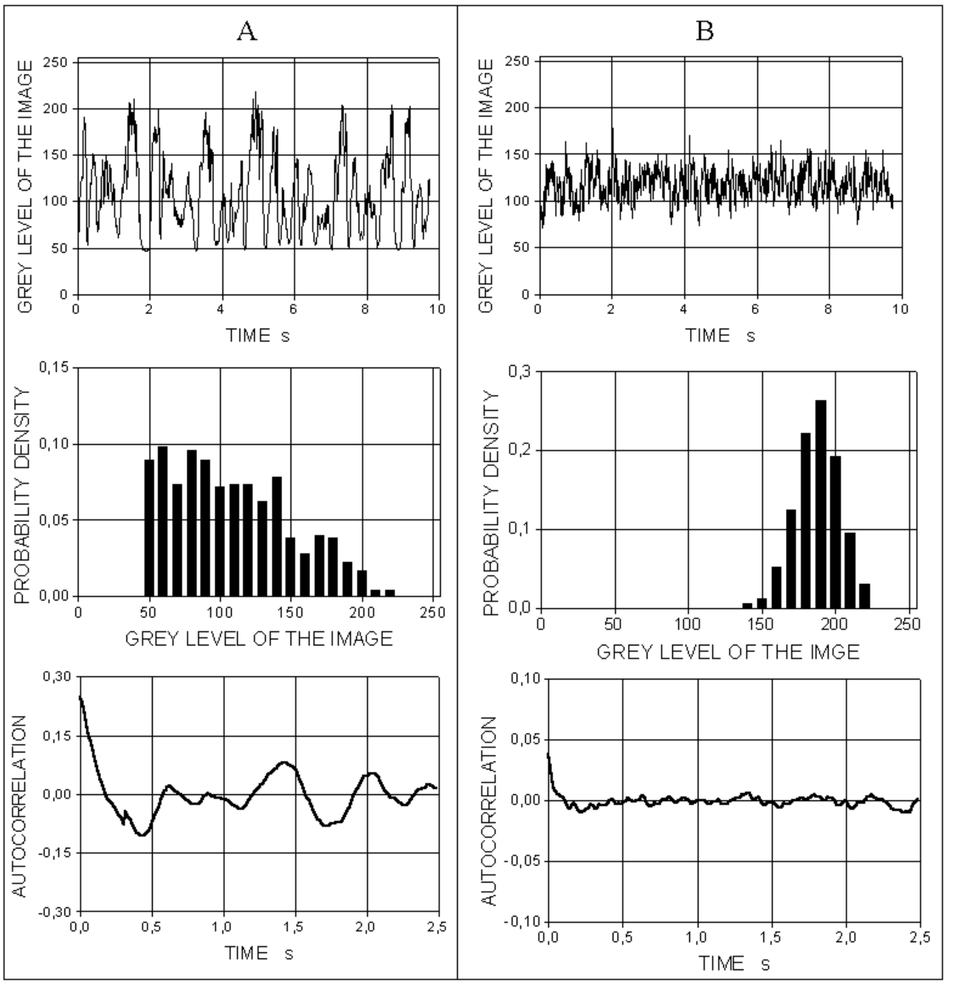

Figure 2. Example results of digital image analysis for A – plug flow regime and B – turbulent flow regime.

In multiphase systems research, experiments are led mostly in laboratory models of apparatuses with simple shape. It is often a vertical riser. But the chambers and flow channels of real devices are not so simple. They frequently change diameter and direction and the two-phase stream reacts with various obstacles.

Digital imaging and analysis of fluidization phenomena – videogrametry – provides a non-invasive measurement tool for recognition of two-phase flow structure, i.e. evaluation of dead zones inside the vessel, tracing trajectories of particles, examination of local void fraction, and for validation of numerical simulations developed in recent years, and much more. Building models of various types of fluidized bed reactors and examining them with the use of videogrametry helps finding specific features of fluidized bed constructions.