Development of Remotely-Controlled Fluidized Bed Reactor for Distance Learning

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1. Introduction

Remote laboratories are an increasingly popular innovation in engineering education and they offer an alternative learning environment to traditional laboratories. Such remote laboratory is developing in the Resource Saving Technologies department of Saint-Petersburg State Technological University. Distance educational complex called «ResTech Remote Lab (RTRL)» is based on a hands-on laboratory-scale process unit. RTRL provides a wide range of educational topics such as hydrodynamic and chemical reaction research, process control and optimization, adjustment of measuring and regulate equipment. Lab work is organized on the basis of internet technology which allows conducting remote experiments from any place without installing additional software on students' computers.

Fluidized bed reactor is the main process element (equipment) of the remote laboratory unit. Fluidized bed reactors are widely used in the chemical industry and are essential to the production of key commodity and specialty chemicals such as petroleum, polymers and pigments.

One of the most significant advantages of the laboratory process unit is that hydrodynamic condition of the catalyst bed is simulated by the physical model while chemical reaction in the reactor unit is simulated by the virtual model on the computer. The virtual model is real time calculated with the aid of the measured hydrodynamic bed condition. Therefore we can use any chemical reaction as an educational example of any chemical process.

2. Remote controlled process unit

The laboratory unit consists of a three-dimensional fluidized bed reactor and a two-dimensional (flat) reactor. An ordinary atmospheric air is used as a fluidized agent which at the same time is the only process feed. The laboratory unit is a completely safe process unit because in the catalyst bed there are no chemical reactions and no really high pressure or temperature occurs in the process. The structural scheme of the process unit and the photo of the remote laboratory are given in figure 1 below.

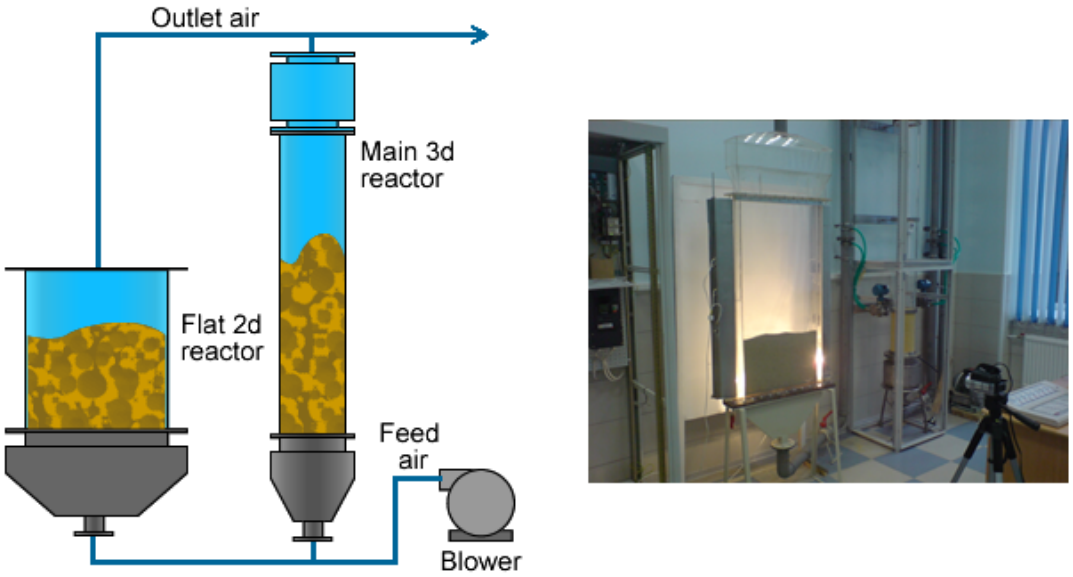

Fig. 1. Structural scheme of the process unit and the photo of the remote laboratory.

The laboratory unit is equipped with a pressure and flow measuring instrument, electrical phase inverter, high resolution video camera and TOSHIBA distributed control system (DCS). DCS has a feed-forward connection with general educational software RTRL for laboratory remote control and hydrodynamic bed condition research. The structure of the distance education complex is represented in the below-given figure 2.

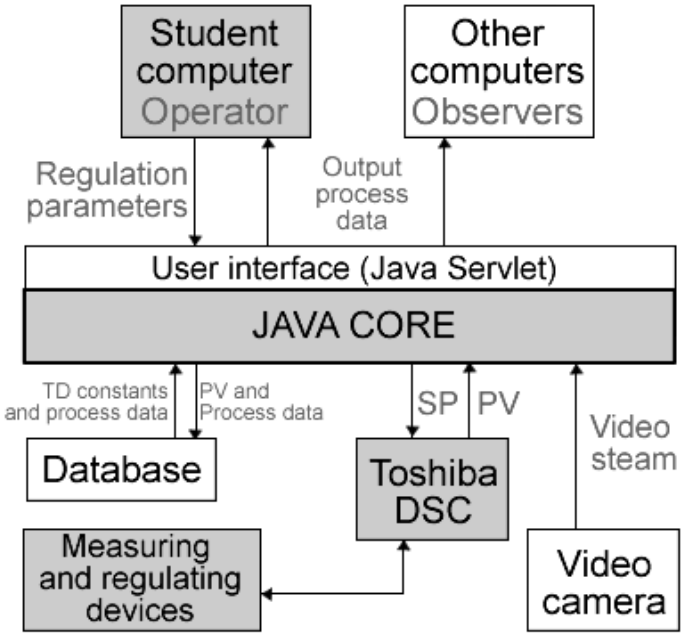

Fig. 2. RTRL structure.

3. Fluidized bed and chemical reaction modeling

Fluidized bed increasing catalyst process in the reaction zone by using internal surface of catalyst (diameter less then 0,04 in). Pore-diffusion resistance is practically reduced. At the same time the chemical reaction is progressing in isothermal condition.

The bubbles of different size are formed in the catalyst bed. Therefore some raw passes through the catalyst bed without physical contact with catalyst fraction. There is correlation between pressure pulsation and bubble size. If the average bubble size is known it is possible to calculate phase-boundary equilibrium coefficients. The bubbles size is researched on additional two-dimensional reactor. Size and distribution of the bubbles are calculated with the processing video frames which video camera takes. That provides to obtain correlation between pressure pulsation and bubbles size which are used in chemical reaction computer model. Therefore the chemical reactions in the main reactor are simulated on the base of actual hydrodynamic bed condition with the pressure pulsation measuring. Some examples of the bubble distribution in two-dimensional reactor are given on figure 3. Video capturing and real time processing are carried by the software developed on JAVA computer language (see Figure 1). Calculated data are used in chemical kinetic model.

Chemical reactions calculated on the base of measured pressure pulsation and gas velocity are in real time mode. It is possible to simulate any chemical reactions which kinetics are known. In the present time RTRL chemical reactions base consists of sulphur dioxide oxidation, butane dehydrogenation and methane oxidation. Chemical reactions are dynamically simulated in two phase model.

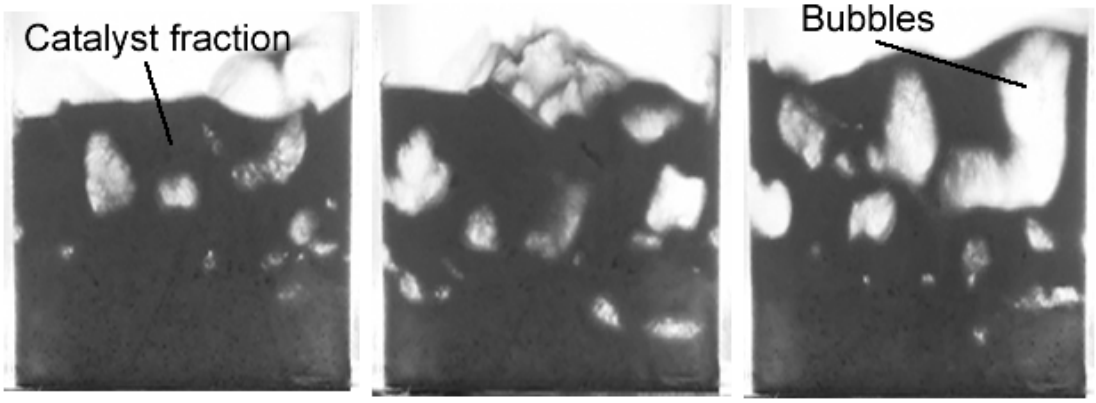

Fig. 3. Some examples of babbles distribution in two-dimensional reactor.

4. Remote control

Laboratory unit is equipped with TOSHIBA distributed control system. In the non distance control mode the regulators set points values are entered from the operator control panel and all the process is displayed on operator monitor. In remote control mode DCS receives the regulators set points values from the RTRL JAVA core. DCS exports present values and other measured parameters to the data base in the real time.

This data exchange provides feedback connection between internet server application (JAVA servlet) and conventional industrial DCS. Server application is internal part of general JAVA core. Students do not install special program for remote education, because RTRL software is developed on JAVA language. All remote lab work is carried out in internet browser (for example Internet Explorer, Opera, Firefox).

5. Distance education process

Remote education is organized entirely through the internet. In the same time only one user has operator function. Other connected users are observers. There are several types of lab work, which are developed on this laboratory unit.

Process startup and control work. First of all the students must research parameters connected with hydrodynamic bed condition (velocity of bed fluidization, distribution and size of bubbles). The next step is to reach technological process rate which provides to produce specify product flow and specify key component concentration in virtual model. The regulate parameters are feed flow ratio and heat exchange mode. The lab work report is automatically generated after the work in Excel. The report consists of PV-parameters trends, regulate parameters and summary table. The work is organized with an operator internet interface.

Fluidized bed hydrodynamic research. The work purpose is to find the correlation between pressure pulsation and bubble size for fluidized bed. The lab work carried out on the two-dimensional reactor using video researching of catalyst bed condition. RTRL program captures the video from video camera and automatically cuts it into frames. Bubble size is calculated by frames processing. Students carry out series of experiments with different pressure pulsation level and line gas velocity speed. The lab work report consists of source data for calculating the correlation out of RTRL program.

PID controller adjustment. The work purpose is to find the optimal regulate parameters (K, Ti). To adjust the line gas velocity regulator we use current frequency in blower electrical line as control parameters. To adjust the virtual feed temperature regulator we use heat exchanger bypass flow rate as control parameters.

6. Remote laboratory additional ability

We plan lab works connected with using of different nozzles. They decrease bubble size in fluidized bed and set better hydrodynamic condition for the chemical reaction. We also plan lab works to research interphase mass exchange coefficient by using gas tracer, for example helium.