# Circulation of catalyst particles in a fluidized bed in the reactor with internal elements and their effect on the reaction of gas dehydrogenation

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Fluidized bed apparatus are widely used in the chemical industry. The advantage is the high speed of heat and mass transfer between components of the reaction, which are resided in different aggregation states. Such apparatus are used in industry for more than fifty years, but interest in the study of properties and applications of the fluidized bed was not lost. New schemes and modernizations of existing technologies are continuously appeared.

One of the available ways to get the data of interest on any processes is a numerical simulation, where the physical phenomenon is associated with the mathematical model. Numerical calculations of fluidization are usually solved by Eulerian-Eulerian approach, when the carrier (gas, liquid) and discrete (solid) phase are considered as continuous. To account for the interaction of particles in the fluidized bed, by analogy with the kinetic theory of gases, was added an equation describing change in the kinetic energy of particles due to their collision (e.g., [1]). The possibility of numerical solution of equations allows to carry out calculations of different variants of the fluidization process, both in terms of basic research and practical application.

A downward movement of the solid particles along the walls with high concentration is observed in fluidization in cylindrical columns. This effect ensures continuous circulation of the particles in the apparatus. Each structural element and the gas feeder in particular make a contribution to the efficiency of the apparatus operability. Location of internal elements on the way of the main flow stream of particles may affect the operation of the apparatus as a whole. This may improve the efficiency of chemical reactions by optimum distribution of the catalyst in gas flow in the study of chemical reactors catalytic processes. Changes in the character of the movement and concentration of particles along the wall with deflectors are shown in [2]. Papers [3, 4] are devoted to experimental and numerical study of effects on the hydrodynamics of the fluidized bed with ring baffles located on the walls of cylindrical apparatus. Experimental studies with internal elements in a liquid-solid fluidized bed are presented in [5]. Investigations of fluidized bed processes in the column with an inner cylinder were experimentally made in [6].

Fluidized bed apparatus of cylindrical shape with a uniform gas feeding are considered in this paper. Ring baffles, deflectors and grids were investigated as internal components. Ring baffles and deflectors on the walls provide a deviation in the downstream zone to the central area. Grids provide breaking of rising bubbles. Both cases with and without clearance between walls and grids are considered. The first aim of present paper was to determine the influence of internal elements on the circulation flow of gas and particles in the apparatus.

The temperature field plays an important role in catalytic chemical reactions. Due to the temperature field is organized continuous circulation of the heated catalyst from the regeneration chamber. The second aim of the paper is to determine effect of circulation flow to the chemical reaction on the example of isobutane to isobutylene dehydrogenation. Isobutane fraction was used as a gas raw. Microspherical aluminum-chrome catalyst particles

of 20-200 micrometers in diameters are located in the reactor. The dehydrogenation of isobutane is accompanied with the release of hydrogen and the absorption of heat. Dehydrogenation reaction of $C_3$-$C_5$ paraffins is thermodynamically feasible only at temperatures 300-900 $^oC$ [7]. Therefore, to maintain the temperature of the reaction gas is supplied at a temperature of 550 $^oC$, and the regenerated catalyst is fed at a temperature of 650 $^oC$. Examples of [8, 9] describe the kinetics of the dehydrogenation of paraffins in fixed and slow movement beds of catalyst. Following them was composed the algorithm that takes into account the conversion of gas, the gas temperature, the volume fraction of catalyst, an elementary volume of reaction area, and the time step.

Differential equations that describe hydrodynamic processes and the processes of heat and mass transfer in the field of computational model of the reactor were solved in CFD package ANSYS Fluent. A full simulation of the reactor unit in differential equations for components mass of the gas mixture is necessary to consider changes associated with chemical reactions. For this problem were written users defined functions (UDF), which added terms of mass transfer and absorption of heat, depending primarily on gas temperature and catalyst concentration.

Hydrodynamic and thermal characteristic operating parameters, such as the field of catalyst concentration and the temperature of gas, were obtained from calculations. Pictures of the main circulating catalyst stream were created and results of influence on the concentration of the catalyst were determined. The effect of internal elements on the behavior of the catalyst in reactor and the efficiency of chemical reaction in the dehydrogenation of isobutane example were investigated.


[1] Gidaspow D. *Multiphase Flow and Fluidization*. Boston: Academic Press, 1994.

[2] Gorliz M.R., Grace J.R. *Augmentation of heat transfer by deflectors on circulating fluidized bed membrane walls* // International Journal of Heat and Mass Transfer. 2002. Vol. 45. P 1149.

[3] Samruamphianskun T., Piumsomboon P., Chalermsinsuwan B. *Effect of ring baffle configurations in a circulating fluidized bed riser using CFD simulation and experimental design analysis* // Chemical Engeneering Journal. 2012. Vol. 210. P. 237–251.

[4] Chalermsinsuwana B, Samruamphianskun T., Piumsomboon P. *Effect of operating parameters inside circulating fluidized bed reactor riser with ring baffles using CFD simulation and experimental design analysis* // Chemical Engineering Research and Design. 2014. Vol. 92. P. 2479.

[5] Piovano S., Salierno G.L., Montmany E., D'Agostino M., Maestri M., Cassanello M. *Bed Expansion and Particle Classification in Liquid Fluidized Beds with Structured Internals* // Chemical Engeneering and Technology. 2015. Vol. 38. No. 3. P. 423.

[6] Gujjula R., Mangadoddy N. *Experimental Investigation of Hydrodynamics of Gas-Solid Flow in an Internally Circulating Fluidized Bed* // Canadian Journal of Chemical Engineering. 2015. Vol. 93. P. 1380.

[7] Beccari M., Romano U. *Encyclopaedia of Hydrocarbons*. Rome: ENI & Istituto della Enciclopedia Italiana G.Treccani. 2006. Vol. 2. P. 687.

[8] Gyngazova M.S., Kravtsov A.V., Ivanchina E.D., Korolenko M.V., Chekantsev N.V. *Reactor modeling and simulation of moving-bed catalytic reforming process* // Chemical Engineering Journal. 2011. Vol. 176-177. P. 134.

[9] Frantsina E.V., Ivashkina E.N., Ivanchina E.D., Romanovskii R.V. *Developing of the mathematical model for controlling the operation of alkane dehydrogenation catalyst in production of linear alkyl benzene* // Chemical Engineering Journal. 2014. Vol. 238. P. 129.