Modeling of the Aerodisperse Systems Hydrodynamics in Devices With Directional Motion of the Fluidized Bed

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INTRODUCTION

Among various dispersed flows, fluidized bed plays the most significant role in modern technology. The fluidization technique has become widely used due to high intensity of processes.

Disadvantages of the fluidized bed device can include (Philippsen et al., 2015), (Haron et al., 2017), (Huili et al., 2017): different residence time of a particle in the device, a need for thorough cleaning of the exhaust air and material entrainment (in particular it is applicable to small particles of the system). In addition, a significant drawback is the return of fine particles back in the fluidized bed zone. The analysis of various fluidized bed granulation equipment in chemical (Caiyuan et al., 2004), food (Patel et al., 2011) and pharmaceuticals (Agrawal and Naveen, 2011) industries showed the urgent need to organize the mutual flow motion, which will enhance the quality of the final product.

It is rational to use the same device for multiple processes in low-tonnage and multi-assortment production in order to reduce the range of the equipment. Implementation of the new forms to organize mutual flows motion (while keeping the same principles of the fluidized phases contact), which would intensify processing of the dispersed materials without considerable increase in the energy costs, is a promising direction for the development of heat and mass exchange processes in the heterogeneous systems (Artyukhov et al., 2019), (Van Ommen et al., 2012).

Among the major techniques of controlling the polydisperse particles residence time in the device, one should notice the following:

1. To develop a direct movement of particles using accelerating elements (gas distributors of vortex type) (Sklabinskyi and Artyukhov, 2013).
2. To design the device with a variable cross-sectional area applied to the granulation, cooling and dedusting process (Ostroha et al., 2019).

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3. The promising direction to reduce financial and energy costs on the heat and mass transfer processes in the fluidized bed is the application of sectioning (vertical and horizontal) to create different conditions for the particle heightwise (lengthwise) motion in the device (Yukhymenko et al., 2016).

BACKGROUND

There are various possibilities to apply suspended layer (fluidized bed, weighted layer). There are many successful cases regarding the introduction of this method in industrial practice, while in others it is at the stage of laboratory research. The processes taking place in heterogeneous systems using the suspended layer method have a great industrial application. It can be used to stove sulphide, arsenic and antimony ores to facilitate the extraction of gold or silver, for pyrite and pyrrhotine roasting to obtain SO_2 in the production of sulfuric acid.

The suspended layer is in great demand in metallurgy for stoving of copper, cobalt and zinc sulfide ores to obtain valuable metals.

Fluidized bed devices for drying solid materials (coal, cement, limestone, etc.) are known in the whole world. Economic considerations make the use of these devices particularly interesting when large-tonnage materials are to be processed. A suspended layer dryer can also be used as a classifier since the drying and classification processes take places simultaneously in the device.

The way to obtain granulation products in the fluidized bed (suspended layer) is used by the world well-known manufacturers of fertilizers and pharmaceutical products: Urea Casale S. A. (Switzerland), Kahl Group (Germany), Stamicarbon (Netherlands), Toyo Engineering Corporation (Japan), Changzhou Xianfeng Drying Equipment Company Ltd (China) Glatt (Germany), Uhde Fertilizer Technology (Netherlands), Rottendorf Pharma (Germany) (Saikh et al, 2013).

The world practice of recent years in the small power engineering has shown that the fluidized bed technology is effective for the utilization of different biomass types, industrial waste and effluents.

The development and implementation of fluidized bed devices are held back in many industries by the lack of reliable methods for calculating them. One of the main reasons is the lack of knowledge of complex and varied processes in the fluidized bed.

When constructing a mathematical model, one should take into account that there is a huge amount of particles in the operating device (Palappan and Sai, 2008). These particles are of different sizes and they move at a different rate in all directions (Ostroha et al., 2017).

Mathematical modeling lets to establish and to optimize mode and technological parameters of the investigated process, as well as to minimize the use of additional automation tools (Trojan, 2015), (Zimmermann and Taghipour, 2015), (Zhaofeng, 2006).

The flows motion hydrodynamics modeling is carried out by the finite-volume method (a numerical method of the differential equations system integration in the differential derivatives). An important benefit of the finite-volume method is that the conservation law of integral values (of the flow rate, of motion quantity) is implemented on every chamber of the computational grid, but not only within it, due to the strong thickening of the computational grid. A closed area of the fluid or gas flow is selected in the calculation. The macroscopic values fields (in this paper – velocity), describing the environment in time and satisfying the definite laws, formed mathematically, are searched for it. The conservation laws in Eulerian variables are mostly used. This model is the most common and the most complicated among multi-phase flow models. The substance of every phase is a solid phase, and the substance motion of

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