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Research Article

Heat and Mass Transfer of Bulk Materials in A Fluidized Bed Using A Lateral Flat Jet

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Abstract

This article examines the mechanisms for intensifying heat and mass transfer processes in fluidized bed apparatuses. Primary focus is placed on the implementation of a lateral flat jet as a method for controlling bed hydrodynamics. The study analyzes the impact of additional jet influence on flow structure, the elimination of stagnant zones, and the enhancement of the heat transfer coefficient,

Keywords:

Fluidized bed, vibro-fluidized bed, heat and mass transfer, bulk materials, classification, energy efficiency.

INTRODUCTION

Fluidized bed apparatuses are widely used in the chemical, oil refining, and food industries for drying, roasting, and conducting catalytic reactions. The primary advantage of such systems is the large phase contact area and high heat and mass transfer coefficients. However, when working with polydisperse bulk materials, issues of bed non-uniformity arise, such as bubble formation, channeling, and the presence of "dead" zones. The application of a lateral flat jet is one of the most promising methods for eliminating these drawbacks and significantly accelerating interphase exchange .

A fluidized bed is formed when the velocity of the fluidizing agent (gas) supplied from below reaches a value where the drag force on the particles equals their weight. At this moment, the bed transitions into a state of fluidization. The introduction of a lateral jet, either perpendicular or at an angle to the main flow, creates a zone of high turbulence. The lateral jet locally increases the Reynolds number, which leads to an increase in the Nusselt number, characterizing the intensity of heat transfer.

The lateral flat jet acts as an active regulator of the bed structure. Gas bubbles rising from the distribution grid collide with the jet and break into smaller fragments. This increases the interfacial surface area. In rectangular apparatuses, particles often accumulate in the corners; however, the flat jet creates a circulation loop, drawing these particles into active motion. The jet imparts an additional tangential velocity component to the particles, which promotes the equalization of temperature and concentration fields. The heat transfer process in such a system includes:

- Convective transfer between the gas and the particle surface.
- Contact heat transfer during the collision of heated particles with each other.
- Heat transfer from the bed to the heat exchange surfaces (walls or coils).

The lateral jet significantly reduces the thickness of the boundary layer on the surface of the particles and the internal elements of the apparatus. This allows for an increase in the heat transfer coefficient by 25–40% compared to a classical fluidized bed without additional jets. Mass transfer (for example, moisture evaporation during drying) is limited by the rate of vapor removal from the material surface. The high velocity of the lateral jet promotes rapid renewal of the near-surface gas layer.

From a thermodynamic perspective, the lateral jet significantly modifies the heat transfer coefficient. By increasing the local turbulence at the bottom or middle layers of the bed, the jet minimizes the thermal resistance of the boundary layer surrounding the particles. This results in a more rapid and uniform temperature distribution throughout the entire volume. Furthermore, the flat geometry of the jet ensures a wider coverage area compared to round nozzles, allowing for a more homogenous interaction with the solid phase. This leads to a substantial reduction in the drying or heating cycle time, directly translating into higher throughput for industrial-scale operations.

Moreover, the use of a lateral flat jet offers a strategic advantage in terms of material quality control. In conventional systems, increasing the air velocity to improve mixing often leads to excessive attrition or the undesired entrainment of fine particles. However, the targeted application of a side jet allows for “active mixing” at lower primary air velocities. This preserves the physical integrity of fragile bulk materials while maintaining high mass transfer rates. Consequently, the combination of a fluidized bed with a lateral flat jet represents a significant advancement in process engineering, offering a pathway toward more compact, energy-efficient, and controllable thermal processing units.

In chemical reactors, this ensures rapid delivery of reactants to the catalyst surface and efficient removal of reaction products, which prevents overheating and side reactions. Modern apparatuses with lateral jet inlets are designed considering the optimal placement of nozzles. This allows for a reduction in the residence time of the material in the apparatus while preserving its thermolabile properties. The jet helps to distribute the binder evenly, ensuring the uniformity of granule size.

The primary constraint limiting the widespread adoption of vibrating fluidized bed apparatuses is their restricted thermal capacity. When operating in a non-entrainment mode, the coolant flow velocity through the bed remains low, which limits the amount of heat supplied and, consequently, reduces the evaporation capacity. Therefore, expanding the application scope of VFB dryers and identifying methods to intensify heat transfer within them represents a relevant scientific and technical challenge.

A potential solution to this problem lies in the use of additional heat supply directly into the bulk of the fluidized bed via vibrating heating surfaces submerged within the bed. This approach allows for:

- A transition to a predominantly conductive energy transfer method;
- A significant reduction in overall air consumption;
- Intensification of the drying process due to direct contact between particles and the vibrating heat exchanger.

Despite these clear advantages, the underlying patterns of drying processes in modified vibrating fluidized bed apparatuses remain insufficiently studied, hindering their precise design and market entry. Within the framework of this work, the objective is to develop an engineering calculation methodology and formulate recommendations for the creation of pilot industrial units.

An essential part of the study is the assessment of noise characteristics at workplaces. Since the vibration drive acts as a source of intense sound pressure, it is necessary to conduct an acoustic environment analysis. If sanitary standards are exceeded, technical solutions for sound insulation and damping must be developed to ensure safe working conditions for the operating personnel.

The effectiveness of modern classifiers used in the industry depends directly on their hydrodynamic regime and design features. Research indicates that in traditional shelf-type apparatuses, intense vortex formation is observed in the central part. This disrupts process stability and leads to the entrainment of large particles by the ascending flow along with the fine product.

Multi-cascade classifiers with a circular shaft cross-section allow for a significant mitigation of these drawbacks. In such apparatuses, the discharge elements are designed as perforated funnels made of individual rings. Diverting the material toward the core of the flow along the entire perimeter ensures high-quality air sifting of particles in the gaps between the rings. For further intensification of the process, gravity-centrifugal classifiers are utilized, where inserts in the form of a helical surface are installed between the funnels. This design offers several advantages.

Combined classifiers are distinguished by their high efficiency and productivity despite their compact dimensions. In such configurations, the material is fed onto a gas distribution grid located beneath the cascade shafts, where it moves in a fluidized state. Separation occurs simultaneously both on the grid and within the volume of the shafts. However, a significant drawback of these systems is their high sensitivity to the moisture content of the raw material: even a negligible amount of moisture leads to the clogging of the grid perforations.

For processing wet materials or those prone to aggregation, apparatuses with transverse or inclined air flow directions are preferred. Unlike vertical shafts, the overflow shelves in these designs serve only to cyclically change the direction of material movement and to break up particle conglomerates. A significant advantage of such configurations is their lower specific energy consumption. In these conditions, improving the purity of the resulting fractions is achieved by directing the air flow at a specific angle to the horizon.

CONCLUSION

The integration of a lateral flat jet into fluidized bed technology represents an effective engineering solution. Despite a slight increase in the structural complexity of the apparatus and additional energy costs for jet delivery, the resulting intensification of heat and mass transfer allows for a significant reduction in equipment dimensions and an improvement in the quality of the final product. The future of this technology lies in the implementation of adaptive control systems, which enable real-time adjustments of jet parameters based on the current state of the bed and the moisture content of the material.

REFERENCES

1. Pavlov, N. V., Shaptala, V. G. Investigation of heat transfer in a fluidized bed under jet action. Izvestiya vuzov. Chemistry and chemical technology. 2012. Vol. 55.
2. Baskakov, A.P. Heat and mass transfer in a fluidized bed. Moscow: Metallurgiya, 1978. 248 p.
3. Gelperin, N.I., Einstein, V.G., Kvasha, V.B. Fundamentals of fluidization technology. Moscow: Khimiya, 1967. 664 p.
4. Sazhin, B.S. Fundamentals of drying techniques. Moscow: Khimiya, 1984. 320 p.
5. Muratov A., Gulyamov S. M. Automation of fluidized bed drying processes. Tashkent: TASHSTU, 2015.