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Combination of physical and mathematical modeling methods in determining the main hydrodynamic parameters of counter-current sieve trays

Abstract

Sieve tray columns are widely used in industry. Their operation is accompanied by the formation of dynamic foam during the interaction of gas and liquid on the tray. Research into hydrodynamics, mass transfer and heat transfer on sieve trays and, in general, distillation and absorption processes, where these contact devices are used, have been going on for over a hundred years and show no tendency towards a decrease in intensity. New designs of sieve trays, both universal and optimized for a narrow area of application in a specific process, continue to be developed and tested.

In dedusting of gaz processes, counter-current sieve trays have advantages over cross-current sieve trays with overflow devices due to their lower tendency to foul holes and simpler design of the device. Dedusting of gaz in sieve tray scrubbers is convenient in the production of granulated salts, since the resulting salt solution is returned to the recycle. It is in such processes counter-current sieve trays have become widespread.

The processes of interaction of media in the foam mode (on sieve tray) are very complex, therefore many parameters required for calculation can be described only by empirical equations. For counter-current sieve trays, where, unlike cross-current trays, the height of the foam layer is not regulated by the overflow height, it is especially difficult to determine the height of the clean liquid layer on the tray. For almost every new tray design, it is necessary to conduct an experimental determination of the permissible operating range for gas velocities, liquid irrigation densities and the corresponding height of the foam layer.

To reduce the costs of physical modeling, studies of the foam regime using computational fluid dynamics (computational fluid dynamics , CFD modeling), however, to date they have not been widely applied to counterflow trays.

The counter-current sieve trays with large round holes used in the production of mineral fertilizers and granulated salts, used for cleaning gas from dust prone to sticking, as well as trays with fixed valves, which have recently become widespread, were selected for the study, but which have not yet been studied for use as counter-current trays.

The use of counter-current trays with 20 and 40 mm holes was tested in industrial installations for the production of granulated salts with the author's participation. Such

trays showed good stability of operation compared to cross-current trays with holes up to 12 mm. We have not found any research results on trays with large holes in the open press.

The aim of the study was to fill in the missing scientific data for the design of an industrial foam apparatus with counter-current plates and a spray eliminator (mist eliminator) and the calculation of the residual content of pollutants in gas emissions.

Tasks:

1. Experimental study of hydrodynamic operating modes of a foam apparatus with counter-current plates, including previously unexplored types of plates;

2. Testing the capabilities of known CFD modeling techniques for simulating a foam layer on counter-current trays, adapting known techniques for a counter-current tray;

3. Study of splash entrainment and the influence of its dispersion on the efficiency of gas purification.

Scientific novelty. For the first time, physical modeling of the operation of counter-current plates with fixed valves was carried out and hydrodynamic parameters of their operating modes were determined.

CFD modeling was performed using the volume fraction of liquid method (volume of fluid (VOF), using the OpenFOAM software package for the foam layer on counter-current trays.

CFD modeling was performed using the interpenetrating media method (the Euler-Euler model) using the ANSYS software package for a foam layer on counter-current trays. The method for calculating the drag coefficient C_D was adapted for modeling a counter-current foam tray.

A method has been developed for calculating the efficiency of gas purification in a device with counter-current foam plates and a wire (mesh) mist collector, taking into account the dispersion composition of droplet entrainment particles.

Practical significance. Experimental studies of counter-current trays with fixed valves were conducted, the recommended range of gas and liquid loads was determined. The advantages of these trays compared to known types of counter-current trays were shown.

The hydrodynamics of a counter-current foam plate was simulated using known CFD modeling techniques in various programs; the applicability limits of known techniques were determined.

A method for CFD modeling of a counter-current foam plate using a model of interpenetrating media with the determination of the bubble resistance coefficient CD is proposed.

A method for design calculation of a foam apparatus is proposed, taking into account the influence of the dispersion composition of the spray on the efficiency of the mist collector and the residual content of pollutants in emissions.

The results of the work will be used by design organizations in the design and calculation of foam devices for wet gas cleaning.

The main provisions for the defense.

1. Results of experimental studies and recommendations for the use of counter-current sieve trays with fixed valves.
2. Results of computer modeling and recommendations for the use of well-known CFD models for sieve trays.
3. A method for CFD modeling of a counter-current foam plate based on the Euler-Euler model of interpenetrating media with calculation of the drag coefficient depending on the velocity and volume fractions of the phases.
4. Methodology for calculating the overall efficiency of gas purification in a foam apparatus with foam plates and a wire mist collector using experimental data on the dispersion composition of droplet spray particles.