Research of efficiency of regular separation pack made of corrugated metal sheets

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Abstract. The separation of heterogeneous systems, of which gas is the solid medium, is a common process of the chemical and oil and gas industries. The quality of gas flow separation affects the efficiency of the entire process. This paper provides a research of the effect of the geometrical dimensions of a regular separation pack composed of corrugated sheets on the efficiency of fine particle capture. Information-measuring system based on simulation using computer simulation using finite element method is proposed for evaluation.

1. Introduction
There are many ways to separate heterogeneous gas mixtures. Their separation is carried out by wet cleaning, filtration and various types of precipitation. The simplest and most economical method of the above, including by means of separation packs, is precipitation. Precipitation is a separation process in which, due to greater density (compared to gas), gravity, inertia or centrifugal forces separate dispersed solid and liquid particles from the continuous gas phase.

The separation apparatus is referred to as separators. Separators are divided by separation methods used, by nature of operation and by field of application. Depending on the composition and properties of the mixture to be separated as well as the desired results, a separation method is selected. According to the principle of operating forces, separators are divided into [3]:
- Gravitational, the separation of phases in which takes place due to the difference in densities of the gas liquid or solid particles of the gas;
- Packed separators in which the phases are separated by gravity and inertia;
- Centrifugal, separation in which takes place due to centrifugal and inertial forces.

2. Design of separation pack
The use of corrugated sheets in pack elements is a promising direction. Thus the design of the pack is developed, which consists of vertically installed corrugated sheets with inclined pleats on each sheet in relation to the direction of gas flow and opposite direction of pleats in adjacent sheets of the package. The pack bags are rotated relative to each other by 90 °. This means that there is quite a lot of space left between the corrugated sheets. Packs of this type have a large proportion of free volume. This in turn means that the pack has low hydraulic resistance, which is an important factor in its selection. This provides lower pressure drop and increased productivity.

The main characteristics of separation packs are:
- particle capture efficiency - determined by the ratio of the amount of precipitated particles to the initial amount;
- aerodynamic resistance - energy consumption when passing the separation pack flow, expressed by pressure loss (difference).

These two parameters are related, such as, for example, improved capture efficiency generally results in increased aerodynamic resistance of the pack.

3. Description of the simulation object

The object of the research is a regular separation pack, which is a pack of vertically corrugated metal sheets installed (figure 1). During the simulation of the separation process, the pack with changes in the unit height parameters \( L \), namely from 100 mm to 350 mm, as well as the pack with a constant unit height of 200 mm, but with changes in the corrugated size (\( h \)): from 10 mm to 35 mm will be considered.

![Figure 1. Corrugated sheet model with characteristic geometric dimensions.](image1)

ANSYS software is used to achieve the goals and objectives.

ANSYS is a universal software system of finite element analysis, it has various software modules for solving complex engineering problems. In particular, ANSYS CFX software module used for calculations of hydro-gas dynamics. This module has a wide range of possibilities of simulating flows of liquids and gases for industrial tasks taking into account turbulence, heat exchange, chemical reactions (figure 2).

![Figure 2. Simulation of the movement of the dispersed phase in the gas flow through the separation pack channel.](image2)
4. Results of evaluation of the effect of the corrugated dimensions on the pack efficiency

The degree of effect of change of the corrugated face (h) of the pack element on the main parameters of the process was evaluated. For this purpose models of the same height of the pack unit L = 200 mm are built, but different dimensions of the corrugation h are from 10 mm to 35 mm in pitch of 5 mm.

Table 1. Capture efficiency for unit height L = 200 mm, ε, %.

| Size of the crimp of the packs element, h, mm | Flow rate, m/s | Average value, ε |
|-----------------------------------------------|----------------|------------------|
|                                               | 0.5            | 0.75            | 1                | 1.25           | 1.5            | 2                | 2.5             | 3                | 3.5             |
|                                               | 10             | 97              | 97              | 97              | 98              | 98              | 99              | 99              | 100             |
|                                               | 15             | 60              | 63              | 66              | 69              | 73              | 73              | 83              | 85              |
|                                               | 20             | 40              | 46              | 57              | 60              | 61              | 66              | 67              | 70              |
|                                               | 25             | 31              | 35              | 40              | 41              | 46              | 48              | 51              | 58              |
|                                               | 30             | 29              | 34              | 38              | 40              | 40              | 40              | 44              | 50              |
|                                               | 35             | 25              | 23              | 22              | 24              | 27              | 28              | 28              | 29              |

Table 2. Results of the separation resistance research.

| Crimp size of the packs element, h, mm | Flow rate, m/s | Average value ξ |
|----------------------------------------|----------------|-----------------|
|                                        | 0.5            | 0.75            | 1                | 1.25           | 1.5            | 2                | 2.5             | 3                | 3.5             |
|                                        | 10             | 218             | 187             | 170             | 158,2          | 151             | 140             | 133,1            | 128,3            | 125,4            | 143,6            |
|                                        | 15             | 150             | 131             | 120             | 113            | 108             | 101             | 96,2             | 93,1             | 91              | 103              |
|                                        | 20             | 117,6           | 106,2           | 100,2           | 96             | 93              | 89              | 86,3             | 84,5             | 83,1            | 90,3             |
|                                        | 25             | 96,4            | 90              | 86              | 83             | 82              | 79,38           | 78              | 77,1             | 76,5            | 80,3             |
|                                        | 30             | 88              | 83              | 80              | 78,3           | 77,1            | 76              | 75              | 74,5             | 74,2            | 76,4             |
|                                        | 35             | 73              | 69,3            | 68              | 67             | 66,3            | 65,7            | 65,3             | 65,3             | 65              | 66               |

On the basis of the obtained data, the average value of the main characteristics of the separation packs, namely the efficiency of particle capture and resistance of the pack, is determined. Analysis of performed calculations and presented graphs shows that efficiency of separation of particles and resistance of packing increases with increase of flow rate in each considered size of sheet corrugations.

However, when considering the results when increasing the corrugated size at the same speeds, the particle capture efficiency and the pack resistance are greatly reduced. Thus, if the face size is 10 mm at a flow rate of 2 m/s, the separation efficiency is 98 %, whereas if the corrugated size is 35 mm at the same speed, the separation efficiency is all 28 %, which is four times lower.

5. Recommendations for practical application of the obtained dependencies

In order to clearly show the dependence of the main characteristics of the separation process of the regular pack on the size of the crimp, we will plot the dependence of the average efficiency of particle
capture and the coefficient of aerodynamic resistance of the pack on the size of the crimp, respectively, Figures 3, 4.

**Figure 3.** Dependence of the particle capture coefficient on the size of the corrugation of the regular separation pack.

**Figure 4.** Dependence of the resistance coefficient on the corrugated size of the regular separation pack.

Having carried out mathematical data processing, established function of determination of efficiency of catching of particles which has an appearance of a polynomial of the second degree: \( \varepsilon = 1,522h^2 - 24.2h + 119 \), it is possible to determine pack resistance by a power function: \( \xi = 141.44h^{-0.41} \). Thus, by determining the results of the simulation of the separation process, the dependencies of the particle capture efficiency and the resistance of the regular separation pack were revealed.

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