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Experimental Determination Of Resistance Coefficients For Nozzles In A Bubble Absorption Device

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Abstract. This article presents the results of experimental research on determining the resistance coefficients of ceramic packing elements of three different sizes used in a bubble absorption device. The efficiency of the absorption process is evaluated through the specific contact surfaces of the ceramic packing elements and the resistance coefficients formed by these surfaces. Based on the research results, the resistance coefficients and specific contact surfaces of ceramic packing elements were determined. Consequently, this has created an opportunity to assess the efficiency of the mass transfer process in the device.

Keywords: Device, bubble, absorption, ceramic packing element, resistance coefficient, hole size, gas velocity and liquid flow rate, mass transfer, specific contact surface

Bubble absorption devices are widely used in industry for carrying out mass transfer processes between gas and liquid[1]. Such devices play a crucial role in processes of chemical separation, neutralization of toxic gases, and production of certain industrial products. Their efficiency is closely linked to the characteristics of the packing materials used in the device. The packing materials are one of the main elements that provide contact between gas and liquid inside the device, and their shape, volume, and materials influence the overall performance of the device[2]. The resistance coefficient of the packing materials, i.e., the quantitative expression of resistance between gas and liquid flows, plays an important role in assessing the hydrodynamic properties of the device. This indicator is necessary to determine the operational stability and economic efficiency of the packing materials. Therefore, conducting scientific research to determine the resistance coefficients of packing materials in bubble absorption devices is of urgent importance. In this study, the resistance coefficients for ceramic packing elements of three different sizes with a rounded shape were experimentally investigated.

Research object

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The object of the research work was an experimental device of a bubble absorber created at the Department of Technological Machines and Equipment of the Fergana Polytechnic Institute and the formula for calculating the resistance coefficient [3,4] obtained as a result of theoretical research.

Results

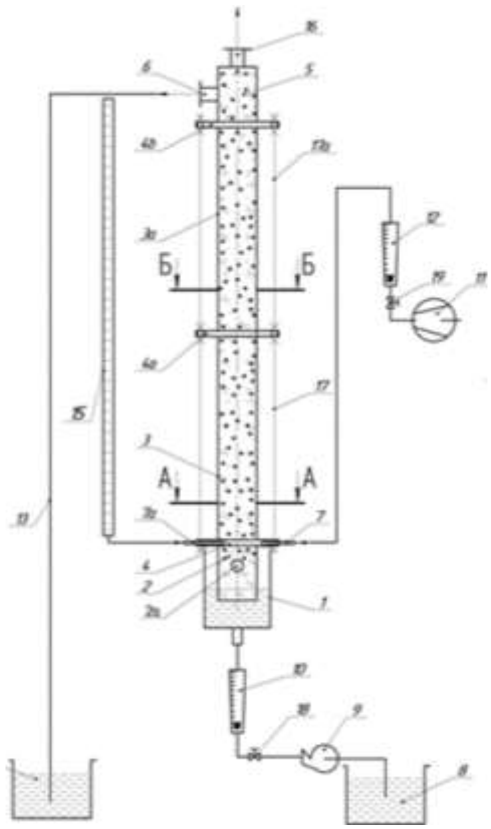

Figure 1. The diagram of the experimental setup.

Fig. 2. Overview

Experimental studies were conducted to determine the resistance coefficients of ceramic fittings of three different sizes installed on a barbotage absorption device [5, 6]. In experimental studies, the relative resistance coefficient of the nozzle is determined by the ratio of the total volume of ceramic nozzles to the volume occupied by the nozzle in the mixing zone of the device. This is because the increase in the volume of the nozzle in the device is directly proportional to the increase in the resistance coefficient. The relative resistance coefficient of the nozzle is determined as follows.

$$\xi_n = \frac{V_n}{V_d} \qquad (1)$$

Where: V_n is the volume of the ceramic nozzle, m^3; V_d is the volume occupied by the ceramic nozzle in the device, m^3.

In gas and absorbent flows, the larger the volume of the nozzle, the resistance coefficient increases, and conversely, the smaller the volume occupied by the nozzle, the resistance coefficient decreases.

First, let's determine the volume of a cylindrical support tank filled with ceramic fittings using formula 2.

$$V = \pi r^2 h \qquad (2)$$

$$V_q = \pi r^2 h = 3.14 \cdot (0.028)^2 \cdot 0.15 = 0.000369 m^3$$

The volume of a single ceramic ball, chosen as a nozzle, is calculated using formula (3).

$$V = \frac{4}{3}\pi r^3 \qquad (3)$$

We multiply the volume of a single ceramic nozzle determined by the total number of ceramic nozzles used to fill the column with a cylindrical support grid. When filled with ceramic fittings with a diameter of d=9 mm, the number was n=169.

$$V = \frac{4}{3}\pi r^3 n = \frac{4}{3} 3{,}14 \cdot 0{,}0045^3 \cdot 169 = 0{,}0000645 m^3$$

Therefore, the total volume of nozzles in the support grid column filled with a nozzle with a diameter of d=9 mm was V = 0.0000645 m3. Let's determine the relative resistance coefficient of the nozzle.

$$\xi_n = \frac{V_n}{V_d} = \frac{0.0000645}{0.000369} = 0.17$$

The relative resistance coefficients of the nozzles with diameters of d=12 mm and d=15 mm were also determined by the same method. According to this, the number of ceramic plates d=12 mm is n=94, the total volume of plates on the supporting grid column is Vn=0.00008507 m3, and the coefficient of relative resistance is ξn=0.23, the number of ceramic plates d=15 mm is n=58, the total volume of plates on the supporting grid column is Vn=0.000102 m3, and the coefficient of relative resistance is ξn=0.28.

The next task is to determine the coefficients of resistance of cylindrical contact elements with a supporting mesh filled with 3 different sizes of nozzles. To determine this, the 3-liter tank was initially filled with water and filled before installing the nozzles in the mixing zone of the device, and the flow time was determined. In the next stage of the experiments, pillars with supporting mesh, filled with ceramic nozzles of 3 different diameters, were installed sequentially in the mixing zone of the device, and research was conducted to determine the coefficients of resistance of each nozzle. The appearance of the ceramic nozzle grains is shown in Figure 3, and their position on the support grid is shown in Figure 4.

d=9mm d=12mm d=15mm

Figure 3. Figure 3. Ceramic nozzle types

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In these experiments, when each nozzle was installed separately in the mixing zone of the device, the aforementioned 3 liters of water were poured into it, and the flow times from each nozzle were determined. The experiments were repeated 5 times for each case. The resistance coefficients of the nozzles relative to the water flow time intervals were determined in cases where no nozzles were installed and installed in the mixing zone of the device.

d=9мм d=12мм d=15мм

Figure 4. Position on the support grid

The average fluid flow time from the device's working zone before the ceramic nozzle's installation was 13 seconds. When conducting experimental studies with ceramic nozzles of three different sizes, used as nozzles, the filling time decreased accordingly as the diameter increased. The average filling time for a ceramic nozzle with a diameter of d_1=9 mm is 22 seconds, for d_2=12 mm it is 20 seconds, and for d_3=15 mm it is 18 seconds. The resistance coefficients of the nozzles were determined as follows.

$$\xi = \frac{t_n}{t_0} \quad (4)$$

Here, t_n is the time of water discharge from the nozzle in a volume of 3 liters, sec; t_0 is the time of water discharge from the nozzle, sec.

Experimental studies have established that for our ceramic fittings with a diameter of 9 mm, the resistance coefficient is ξ=1.7 to ξ=1.5 at d=12 mm and ξ=1.3 at d=15 mm (Table 1). The obtained experimental results were processed using a computer program and a graph of the dependence was constructed (Fig. 5).

№	Experimental fluid Volume, [Liters]	Before installing the nozzle	Position with nozzle					
		fill time t (seconds)	Ǿ 9mm	ξ	Ǿ 12mm	ξ	Ǿ 15mm	ξ
1		14.15	24.63	1.74	21.11	1.51	18.08	1.28
2		13.09	22.51	1.71	20	1.52	18.14	1.32

3	3	12.94	22.70	1.75	20.89	1.61	18.40	1.35
4		13.52	22.82	1.68	20.56	1.52	19.06	1.4
5		13.91	23.01	1.65	20.78	1.5	18.02	1.3
		Average 13 seconds	**22**	**1.7**	**20**	**1.5**	**18**	**1.3**

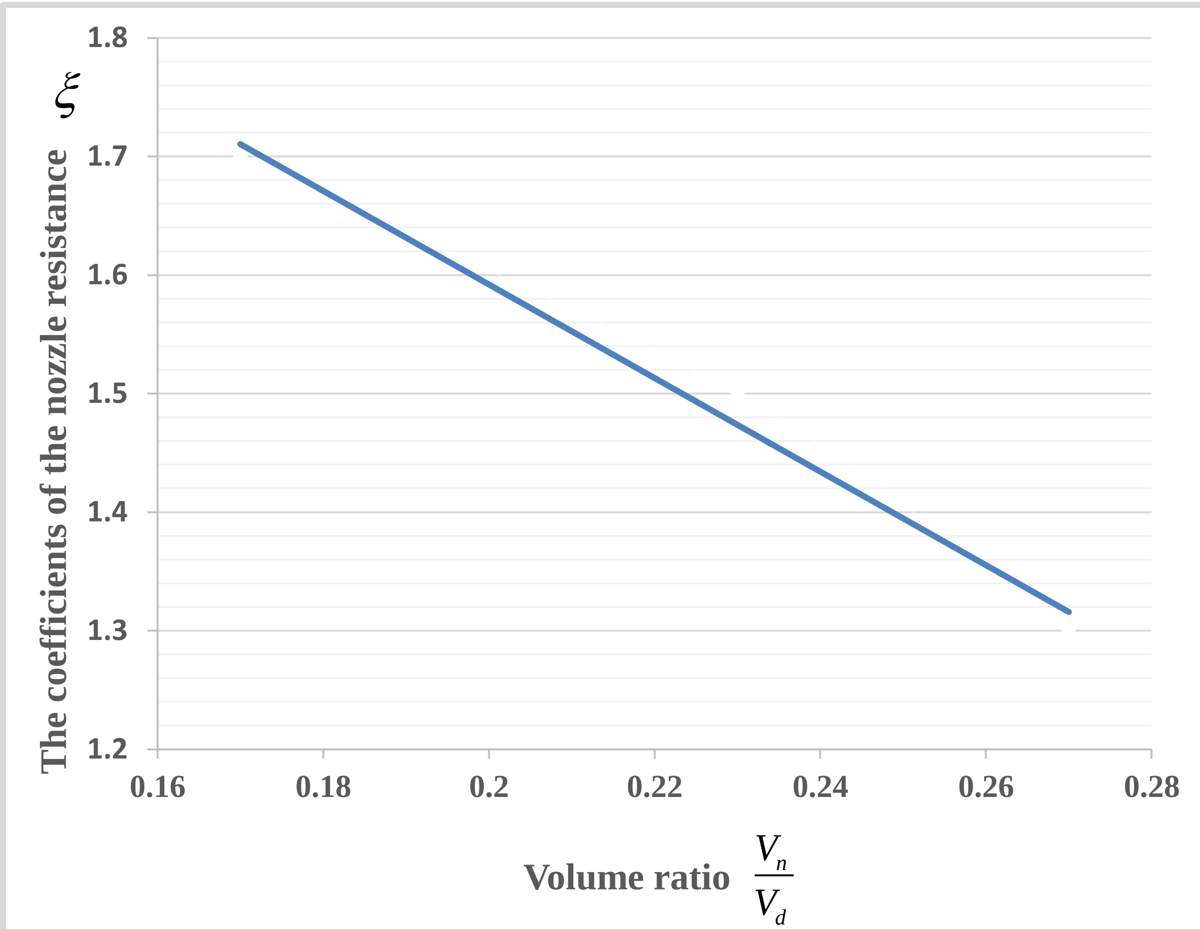

Figure 5. The graph of the change in the resistance coefficient depends on the volume of ceramic fittings.

The obtained regression equation looks like this

$$y = -3{,}9474x + 2{,}3816 \qquad R^2 = 0{,}9868$$

Above, we have determined the coefficient of relative resistance of ceramic fittings. The next task is to determine the value of the correction coefficient depending on the resistance coefficient and the relative resistance coefficients determined as a result of experimental research.

We define the correction coefficient as follows.

$$\Delta K = \frac{\xi}{\xi_н}$$

To do this, we divide the coefficient of resistance ξ, found experimentally, by the coefficient of relative resistance ξn.

$$\Delta K = \frac{\xi}{\xi_н} = \frac{1.7}{0.17} = 10$$

The correction coefficients for the dimensions of the subsequent ceramic nozzle were determined in the same way. Our ceramic fittings with a diameter of 12 mm were 94 pieces, with a volume of Vn=0.00008507 m3, a relative resistance coefficient of ξn=0.23, and a correction coefficient of =6.5. We obtained 58 ceramic fittings with a diameter of 15 mm and a volume of Vn=0.000102 m3, with a relative resistance coefficient of ξn=0.27, and a correction coefficient of =4.8. The obtained experimental results were processed using a computer program and dependence graphs were constructed (Fig. 6).

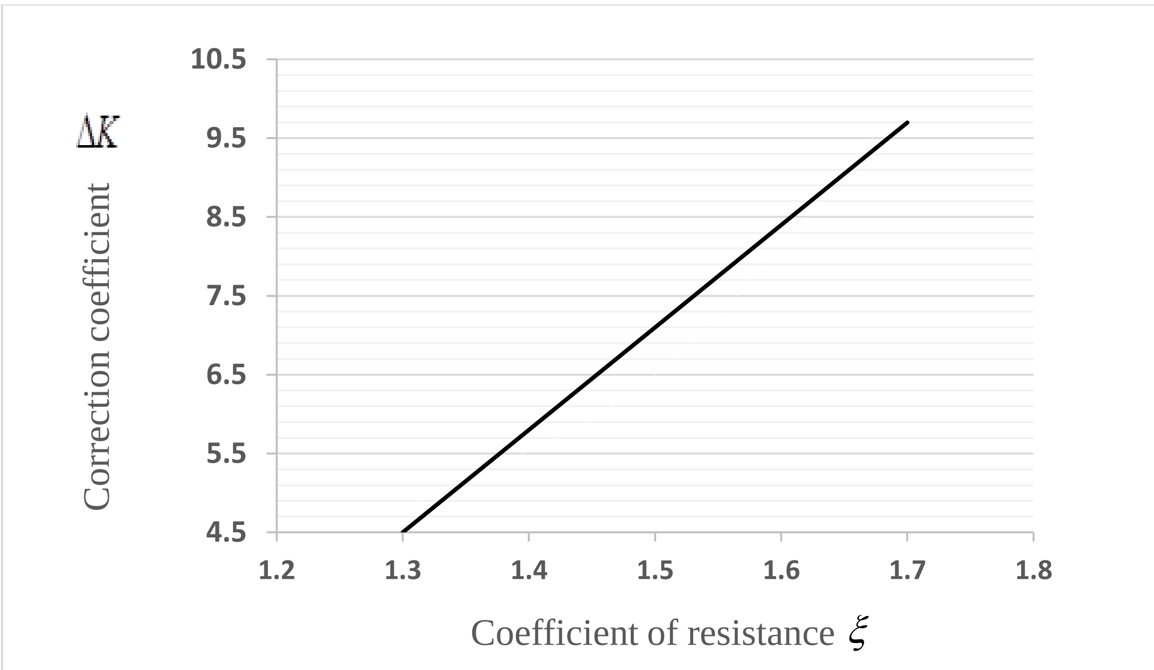

Figure 6. The graph of the change in the correction coefficient depends on the specified resistance coefficient of the ceramic fittings.

The form of the obtained regression equation

$$y = 13x - 12,4 \qquad R^2 = 0,9616$$

Mass transfer processes are mainly carried out on the surface of the diameter of the ceramic nozzle, which creates the coefficient of resistance and the coefficients of resistance. Therefore, it is important to determine the specific contact area. The surface area of a ceramic nozzle with a diameter of d_1=9 mm and a quantity of n=169 pieces is determined as follows:

$$S_k = 4\pi r^2 \cdot n \qquad (5)$$

$$S_k = 4\pi r^2 \cdot n = 4 \cdot 3.14 \cdot (0.0045)^2 \cdot 169 = 0.043 m^2$$

The specific contact surfaces of the remaining nozzles were determined using the same method. The surface area of the ceramic nozzle with a diameter of d_2=12 mm and a quantity of n=94 pieces was equal to S_k=0.0425 m^2. The surface area of the ceramic nozzle with a diameter of d_3=15 mm and a quantity of n=58 pieces was

S_k=0.0409 m2. The obtained experimental results were processed using a computer program, and a graph of the dependence was constructed (Fig. 7).

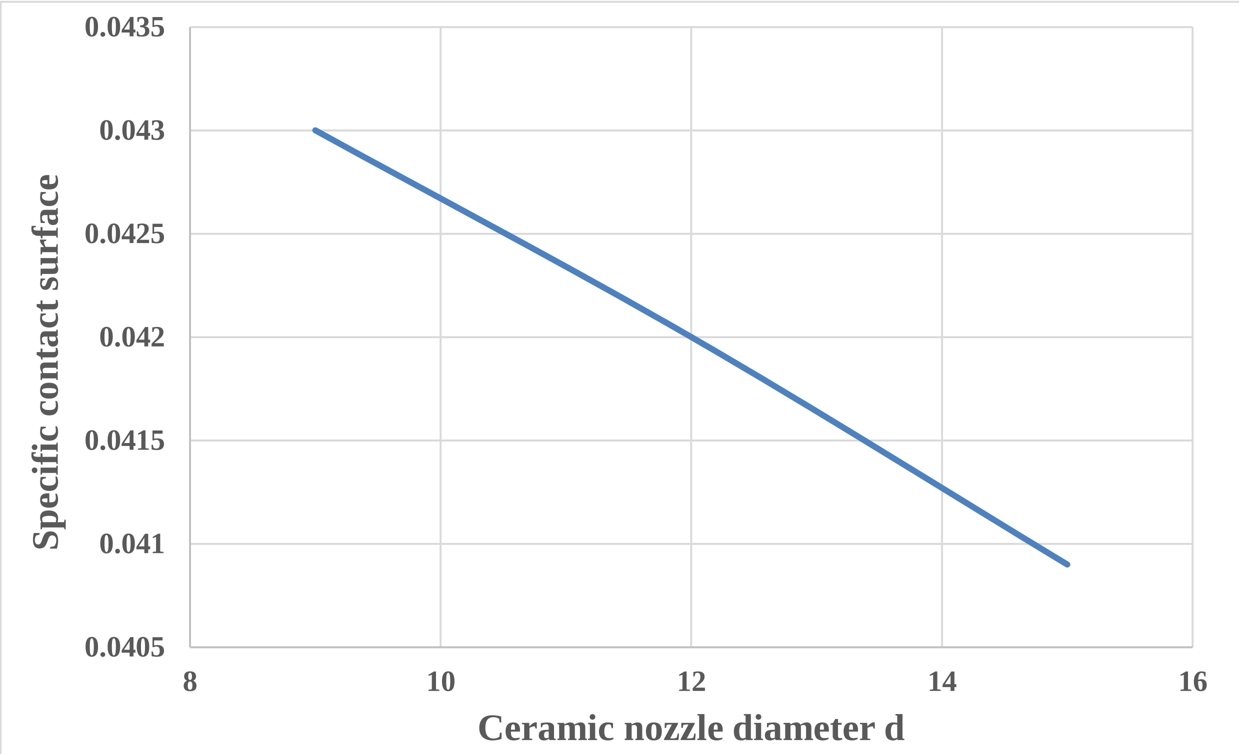

Figure 7. Graph of the dependence of the specific contact surface on the diameter of the ceramic nozzles

The form of the obtained regression equation

$$y = -0{,}0003x + 0{,}0462 \quad R^2 = 0{,}9992$$

Conclusion

Experimental studies have determined the resistance coefficients of ceramic fittings of three different sizes used in the bubble absorption device. Based on the research results, the values of the correction coefficients were determined to calculate the resistance coefficient of the selected ceramic fittings. The specific contact surfaces of spherical ceramic fittings were also determined, which are important in determining the effectiveness of the mass trade process.

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