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WAYS TO INCREASE THE AERODYNAMIC EFFICIENCY OF VENTILATION SYSTEMS

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Abstract

It has been proven that the aerodynamic efficiency of a ventilation system can be increased by reducing aerodynamic losses in the functional units of the supply/exhaust unit, in shaped parts, reducing the speeds in air ducts, etc. If losses in the main branch of a complex ventilation system are minimized, then reducing aerodynamic losses in the branches does not increase its efficiency. There are other ways to increase the efficiency of ventilation systems, which will be discussed in this article.

Keywords: Ventilation Systems, air supply system, natural ventilation system of a building , aerodynamics .

Introduction

Let us consider an air-cleaning system consisting of three branches directly originating from the air-cleaning unit (Fig. 1), with distributed air distribution.

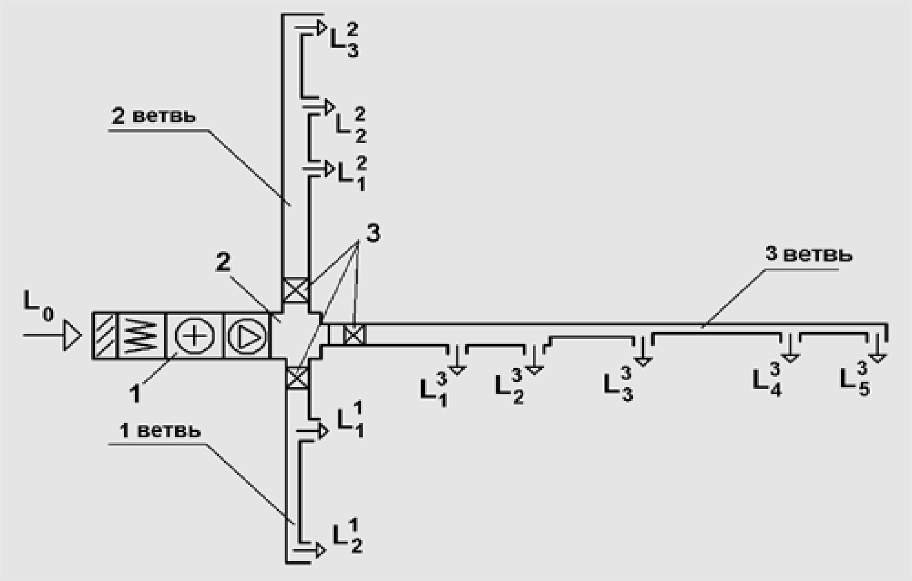

Figure 1. Ventilation system diagram: 1 – air supply unit; 2 – “disassembly chamber”; 3 – throttles

For ease of perception, the pressure losses are shown in the figure proportionally to the length of the air duct, and the performance is proportional to its thickness. Let us assume that the static pressure at the outlet of the air-cleaning unit is significantly greater than the dynamic pressure of the air flow in the air ducts.

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When calculating the required fan pressure, the main branch is selected, in our case it is the 3rd branch. The fan of the air handling unit (hereinafter referred to as the main fan) is selected for a given flow rate and total pressure p_{vo}, equal to the losses in the air handling unit, plus the losses in the main branch.

In standard design practice, aerodynamic losses in the 1st and 2nd branches should be equal to losses in the main line, i.e. their losses should be artificially increased, and accordingly, the total losses of the ventilation system also increase. This is usually done in various ways, for example, by increasing the speed in the air ducts, installing throttle washers, etc. Directly in each of the branches, the specified flow rate through the distributing devices can be obtained by increasing the resistance of the distributing devices themselves: installing diaphragms, covering the grilles, etc. In the future, both of these will be referred to as "throttling" and will be called passive impact on the network.

Power losses during "throttling" are determined by the formula

$$N_{dros} = L_{dros} \cdot Dp_{dros} / \eta_{v},$$

where $L_{throttle}$ is the flow rate through the throttle; $Dp_{throttle}$ is the pressure drop across the throttle; h_{v} is the total efficiency of the fan.

In order to reduce losses associated with "throttling", we will design all branches with minimal aerodynamic losses. We will select the branch with minimal losses as the main branch, and in the remaining branches we will install fans-closers that compensate for the corresponding excess of losses (Fig. 2). Since such an effect on the ventilation system leads to a decrease in the overall aerodynamic resistance, then, in contrast to passive "throttling", we will call it active.

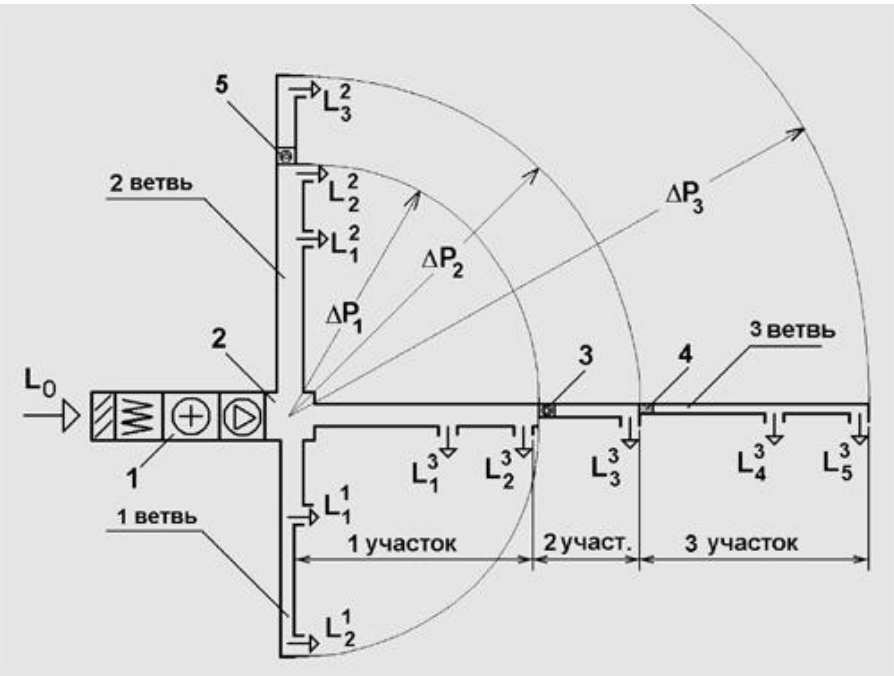

Figure 2. Active impact on the ventilation system: 1 – air supply unit; 2 – disassembly chamber; 3, 4, 5 – fan coils

Let's install:

– in the “disassembly chamber” the pressure is equal to the losses in the first branch;

– in branch 2 – fan-cooler 5 with a capacity of L_3^2 and a pressure equal to $Dp_2 - Dp_1$;

– in branch 3 – fan-coupler 3 with a capacity of $L_3^3 + L_4^3 + L_5^3$ and a pressure equal to $Dp_2 - Dp_1$;

– in branch 3, at the point where the pressure losses are equal to the pressure losses in the 2nd branch, a fan-coupler 4 with a capacity of $L_4^3 + L_5^3$ and a pressure equal to $Dp_3 - Dp_2$.

the fan of the air handling unit must have a total pressure equal to the losses in the unit, plus the losses in the 1st branch:

$p_{vo} = S\Delta p_{\text{приті}} + Dp_1$, and the consumed power $N_{vo} = L_o \bullet p_{vo} / h_{vo}$. The total consumed power of all fans $N_{v\Sigma} = N_{vo} + N_{\text{в.д1}} + N_{\text{в.д2}} + N_{\text{в.д3}}$; where $N_{\text{в.д3}}$, $N_{\text{в.д4}}$, $N_{\text{в.д5}}$ are the consumed power of the air handling units. Aerodynamic efficiency of the supply system [1]: $h_{\text{прит}} = L_o (S\Delta p^{\text{н}}_{\text{приті}} + SL_i \times V^2_{\text{выхі}} / 2) / N_{v\Sigma}$.

In networks with parallel branches (coming directly after the air-cleaning unit), in some cases it is preferable to maintain static pressure close to zero in the "parsing chamber". We will call this element of the air-cleaning unit a "zero static pressure chamber" (Fig. 3). The main fan supplies the required amount of air to the chamber, overcoming only the aerodynamic losses of the air-cleaning unit. Air is parsed from the chamber by fan-closers, each of which works for its own branch.

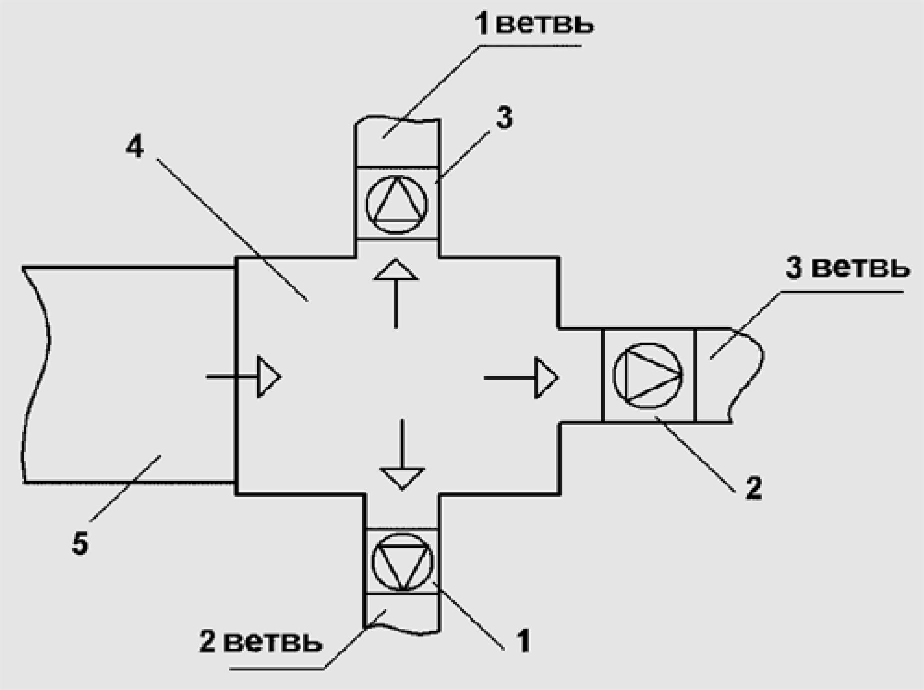

Figure 3. "Zero static pressure chamber": 1, 2, 3 - air handling fans; 4 - zero static pressure chamber; 5 - air supply unit

Let us consider examples of the aerodynamic efficiency of a ventilation system under various options of passive and active influence on it.

We assume that it is necessary to supply 18,000 m3/h of clean air to points A and B of the room (Fig. 4), with the main branch aA (branch 1) determined by the configuration of the room and the aerodynamic losses in it being minimized. Air can be supplied to point B by various routes (aB , bB , cB), as well as by means of an independent air-cleaning unit.

Let's accept the following conditions when designing a ventilation system:

– the air ducts have the same cross-sectional area of 1 m2 , the flow velocity in the air ducts $V_1 = V_2 = 5$ m/s;

– the total coefficient of internal aerodynamic losses of the main line, determined by the speed in the air duct, $z_1 = 30$;

– the flow exits directly from the air ducts at a speed of $V_{out} = 5$ m/s;

– losses associated with the flow outlet are equal to $\rho V_{out}^2 / 2$, total losses directly in the main branch (taking into account the outlet losses) $Dp_1' = \rho V_1^2 / 2\ (z_1 + 1)$;

– the total efficiency of the fans is 0.8;

– losses in the supply unit (inlet valve, filter, heater, muffler) are equal to the “standard” ones: $SDp_{\text{приті}} = 370$ Pa.

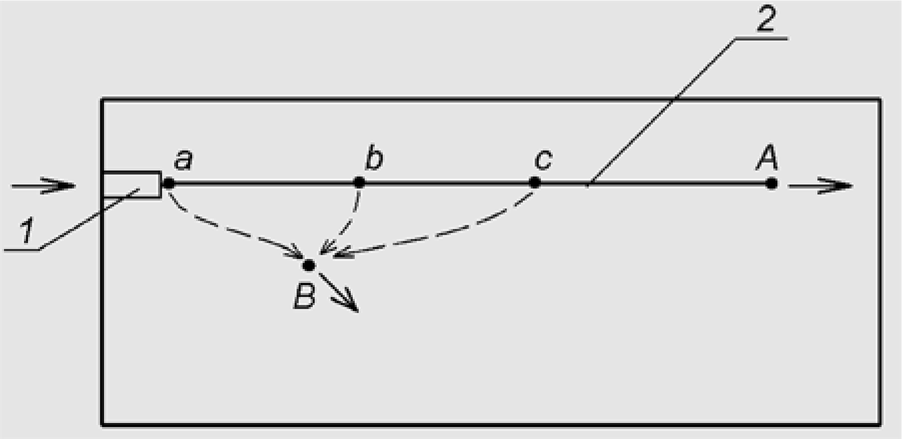

Figure 4. Air supply diagram to the room, aA – main branch

A ventilation system with parallel branches, but with concentrated distribution (air distribution from one air distribution device in each branch).

Option 1. We design an air-cleaning unit with a capacity of $L_0 = 36{,}000$ m ^{3} /h, operating on two parallel branches (the 1st branch is the main branch). Let us assume that we managed to design the second branch of minimum length with a total coefficient of internal aerodynamic losses $z_2 = 5$ (Fig. 5).

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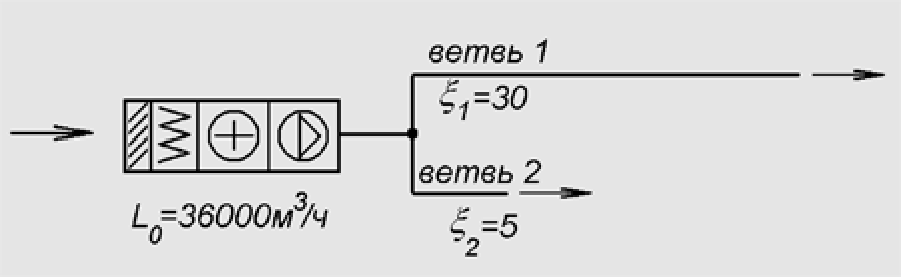
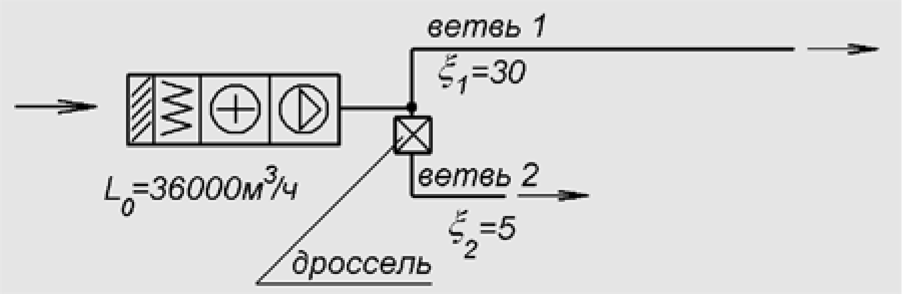


Figure 5. Ventilation system with two parallel branches, without balancing of performance in the branches

Let's turn on the fan. If no measures are taken to equalize the aerodynamic losses in the branches, then the flow rate across the branches will be distributed inversely proportional to the total losses. The capacity in the 1st branch in this case will be equal to 3.06 m3 / s, and in the second - 6.94 m3 / s (the solution is not given in order not to complicate the example), while the corresponding velocities in the air ducts are: 3.06 and 6.94 m/s, respectively. The total pressure losses directly in the first and second branches (taking into account the losses with the outlet velocity) will be equal to SDp' $_{1.2}$ = 174 Pa*. Total losses of the network: Dp $_c$ = SDp' $_{ci}$ + SDp $_{приті}$ = 544 Pa, and the power consumed by the fan N $_{vo}$ = 6.8 kW (here p $_{vo}$ = Dp $_s$).
Efficiency of a ventilation system with unbalanced flow rates: h $_p$ = 0.567 (determined based on the average flow rate of 5 m/s).

Option 2. As is accepted in standard practice of designing ventilation systems, to equalize the costs, we introduce additional aerodynamic resistance into the 2nd branch (Fig. 6), equal to the difference in total losses in the branches Dp $_{dros}$ = Dp' $_1$ – Dp' $_2$. It should be understood that this increases the overall resistance of the system (compared to a system without balancing the costs).



At a given flow rate, the total losses of the 1st branch are 465 Pa, and the 2nd 90 Pa. The pressure drop on the throttle: Dp $_{throttle}$ = 375 Pa (a similar effect can be obtained by reducing the cross-section of the air duct of the 2nd branch and a corresponding increase in speed to 11.36 m/s). Power losses on the throttle

$$N_{dros} = L_2 \bullet Dp_{dros} / h_v = 2.34 \text{ kW}.$$

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The total pressure of the fan must be equal to the total losses of the ventilation system – 835 Pa. The power consumed by the fan N $_v$ = 10.44 kW, of which 2.34 kW is lost on the throttle.

The efficiency of the ventilation system is 0.369, that is, due to the increase in aerodynamic losses in the second branch (by 291 Pa), it decreased by 35%.

The efficiency of the ventilation system is 0.476, i.e. equal to the efficiency of a ventilation system with parallel branches and with fan coils.

“Equivalent” pressure losses in the system are 648 Pa, which is 22% less than when “throttling” the first dispensing device.

For clarity, we will summarize the calculation results in a table and give a brief analysis of the results obtained. It should be borne in mind that in addition to the noted increase in aerodynamic efficiency, there is also a decrease in the noise level emitted by the fans. For a simplified analysis, we will assume that the total noise emission of several fans is equal to the emission of one fan with a capacity equal to the total capacity of the fans, and with a total pressure equal to the "equivalent" losses in the ventilation system. The assessment of the corrected sound power level at the output was made by recalculating the acoustic characteristics of the VR 80-70-10-01 and VR 80-70-12.5-01 fans.

Comparison of methods of influence on ventilation systems:

1. Ventilation system with parallel branches and concentrated distribution (air distribution from one air distribution device in each branch).

Active intervention to reduce the overall aerodynamic losses of the system by dividing it into two independent ventilation systems and installing fan-couplers together with a "disassembly chamber" or "zero static pressure chamber" resulted in an increase in aerodynamic efficiency by 29%. At the same time, the equivalent sound power level of the fan decreased by 3 dBA (in absolute terms, this is a 2-fold reduction in radiated power).

2. Linear ventilation system with distributed distribution.

Active intervention to reduce overall aerodynamic losses of the system by dividing it into two independent ventilation systems and installing a fan-coil resulted in an increase in aerodynamic efficiency by 29%. At the same time, the corrected sound power level of the main fan decreased by 3 dBA .

This article does not consider the possibility, conditions and economic feasibility of using various methods of active influence on ventilation systems. In this article, we only considered methods of increasing the aerodynamic efficiency of ventilation systems, omitting such well-known methods as reducing the speed in air ducts, losses in fittings and supply/exhaust units, etc.

Let us list the basic principles of constructing aerodynamically efficient ventilation systems (with minimized losses associated with “throttling”).

1. Preference should be given to simple (non-branched) ventilation systems.
2. In ventilation systems with branched air ducts:

– branches with low aerodynamic losses and relatively high flow rates should be excluded;
– branches should be designed with approximately the same aerodynamic losses to avoid "throttling" when balancing flows;
– when actively influencing the ventilation system, a branch with a relatively high flow rate and minimal aerodynamic losses should be selected as the main branch, and fan-couplers should be used in the remaining branches.
3. In ventilation systems with linear air ducts and with distributed supply/exhaust, the air ducts should be divided into a number of sections, at the beginning of which it is necessary to install fan-coils that compensate for the corresponding aerodynamic losses.

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