Some aspects of ventilation system quality indicators

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Abstract. The article analyzes the factors affecting the performance and efficiency of industrial ventilation systems, as well as evaluated the technology and constructive reliability of indoor climate systems. The purpose of the work was to find ways to improve energy efficiency as a priority indicator of modern industrial ventilation systems in conditions of significant and ever-increasing need to save energy consumption costs. The work uses analytical research methods based on theories of probability and reliability of technical systems, analysis of known scientific and own practical results. In the course of the study, the results were obtained allowing to estimate the efficiency of the ventilation system not only in terms of the installed capacity and efficiency of the ventilation unit, but also taking into account such important indicators as energy efficiency, process reliability and functional purpose of the system. The ways of increasing the complex aerodynamic parameter of the ventilation system with the possible elimination of energy costs are determined.

1 Introduction

Creating and maintaining the required air quality in residential and public buildings, safe working conditions in industrial premises of industrial enterprises, as well as the solution environmental problems is impossible without effective and reliable operation of ventilation systems [1]. They are designed to remove harmful emissions from manufacturing machinery and provide the necessary air exchange in the premises.

Much attention is also paid to the problems of energy saving, since the operation of ventilation and gas cleaning systems makes a significant contribution to the energy consumption of enterprises [2-4]. Insufficient efficiency and low durability of ventilation equipment lead to irrational energy consumption, equipment downtime, accidents and associated large financial costs [5].

The ventilation system includes a significant number of structural elements, the failure of which can lead to its malfunction, or to early wear of the major components, violating its technological reliability. The average planned operating time for failure of the ventilation system as a whole is more than 20,000 hours. However, for the operation of the ventilation system, it is necessary to connect the ventilation unit's electric motor to the power grid

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through a control system that includes an incoming switch, a magnetic starter, a thermal relay, control buttons, and an automatic shutdown relay in case of fire (see Fig. 1).

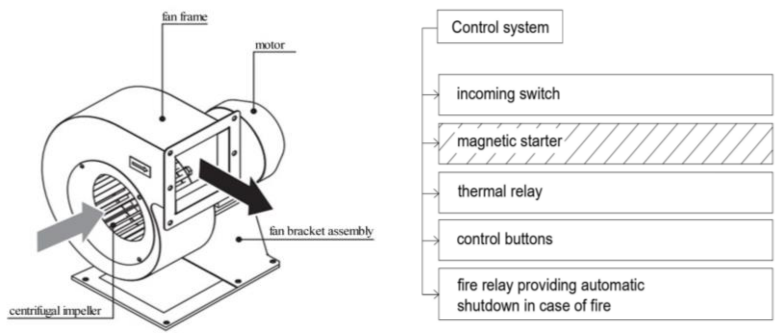

Fig. 1. Diagram of the radial fan and its control system.

2 Discussion

Risk analysis of the air handling unit control system identifies the magnetic starter as a component with minimal reliability. Table 1 shows the reliability characteristics of some elements of the ventilation system [6, 7].

Table 1. Characteristics of the ventilation system elements.

No.	Name of the ventilation system element	Average time between failures, an hour	Note
1	Radial fan of the ventilation system	10 000	According to the technical regulations
2	Air handling unit AVMD18500L	20 000	
3	Magnetic starter	16 000	

The probability of nonfailure works is calculated by the formula (1) at the accepted failure rate λ, h-1

$$P(t) = e^{-\lambda \cdot T} \qquad (1)$$

where:
$P(t) = e^{-0,0000107 \cdot 20000} = e^{-0,214} = 0,808$
Then the probability of nonfailure works during normal operation will be:
$P(t) = e^{-0,0000107 \cdot 10000} = e^{-0,107} = 0,89,$
$P(t) + Q(t) = 1,$
therefore, the probability of fan failure
$Q(t) = 1-0,89= 0,11.$
The technical risk assessment R_t, can be calculated by the formula (2)

$$Rt = \Sigma\, \Sigma\, \lambda\, i \cdot Qij \qquad (2)$$

where *i* – the number of possible failures;
j – the number of impact cases in the *i*-th failure.
For the considered option, the value of the technical risk will be $1,18 \cdot 10^{-8}$.

When designing a ventilation system, performance and aerodynamic losses are taken into account, but determining only the required installation power and the efficiency of the air handling unit is impossible to evaluate the concept of «the ventilation system efficiency». It is also necessary to take into account the energy efficiency, technological reliability and functional purpose of the system [1]. It is necessary to distinguish the following ways to reduce the energy consumption of the ventilation system. This is the elimination of irrational use of energy and its losses, as well as increasing the efficiency of using "helpful" energy costs. For example, when reducing the volume losses caused by air leaks and a suction effect through the leaks of the ventilation network elements (see Fig. 2).

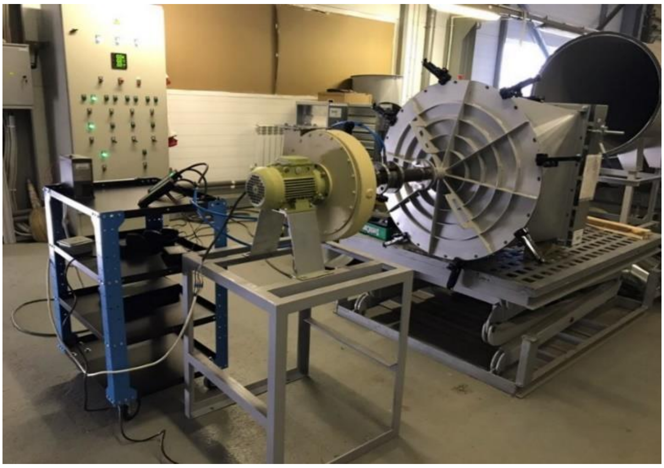

Fig. 2. Laboratory stand for testing the ventilation valve for tightness.

Figure 3 shows a diagram of the pressure in the flow of the duct ventilation valve, where it is possible to visually determine the sections of the network with high and low pressure, the most dangerous from the point of view of leaks, and, consequently, reducing the aerodynamic efficiency and energy efficiency of the ventilation system [8-10].

To increase the aerodynamic efficiency and the complex energy parameter of the ventilation system, it is necessary to eliminate volume losses by increasing the reliability of ventilation equipment, in particular, ventilation valves for various purposes.

The expression for the complex energy parameter of the ventilation system EPVS can be written as

$$EPVS = N_п / N .Q = EFg – EFo - EFmex / Q \quad (3)$$

where N_n – available fan power, *W*;

N – fan power consumption, *W*;

Q – fan capacity, m^3/s;

EF_g, EF_o, EF_{mex} – the values of the efficiency factor of hydraulic, volumetric and mechanical.

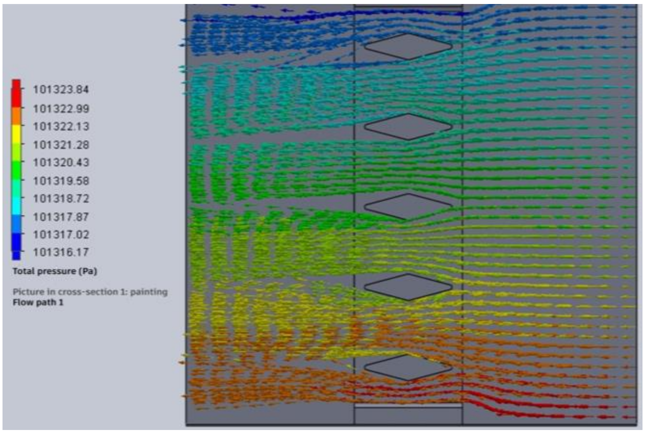

Fig. 3. Distribution of the total pressure in the flow of the channel valve.

Each of the considered efficiencies characterizes its own item of energy costs of the ventilation system for their comparative analysis and making optimal technical decisions, thereby affecting their energy efficiency [11, 12].

Due to the variety of factors that determine the reliability of complex technical systems, such as ventilation systems, risk analysis, as an integral part of risk management, must be performed for each specific product.

3 Materials and methods

The ventilation system is designed to solve a set of tasks to create and maintain the required quality of internal air and certain parameters of the microclimate of premises for various purposes. It itself is a complex technical and technological system, consisting of ventilation equipment designed for air treatment and a ventilation network for its transportation [13, 14].

The operating capacity and efficiency of ventilation systems depends on many factors and the associated technological and structural reliability and associated risks.

The risk assessment of technological systems [1], including ventilation systems, is based on the determination of both the probability and the size of the adverse consequences of their action.

A number of harmful factors that have arisen as a result of non-compliance with technical regulations and design and operational indicators are considered, while analyzing three main issues: which element can fail (hazard identification); with what probability it can occur (frequency analysis); what are the consequences of this event (consequences analysis).

In order to improve the efficiency of ventilation systems, it is necessary to analyze the costs of ensuring its technological reliability [15]. To do this, you should rank the factors and highlight the main indicators, breaking them down into groups:

– indicators of sanitary and hygienic reliability of ventilation systems;
– indicators of technological reliability;
– indicators of energy consumption.

Reliability is an important indicator that determines the technological consumer properties of ventilation systems and is close in terms of the probability of non-failure works Pt [16].

Reliability (P) is a probabilistic characteristic of the ventilation systems operation and depends on the selected system performance and the reliability of the components of a complex technical system, that is, both on the equipment of this ventilation system and directly on the ventilation network itself.

4 Results

The following efficiency indicators characterize ventilation systems for industrial premises of industrial enterprises, the data on which are analyzed in Tables 1 and 2 of this article:

– air heating system with a loaded reserve heating unit P= 0,91;
– air heating system with an unloaded reserve heating unit P= 0,95;
– air heating system with an unloaded reserve fan P= 0,52;
– exhaust mechanical ventilation system P= 0,51;
– exhaust mechanical ventilation system with a reserve fan P= 0,85.

At the same time, the evaluation of the efficiency of ventilation systems and the subsequent, if necessary, development of proposals to increase their efficiency should be carried out by the method of joint analysis of the efficiency components of ventilation systems and the efficiency of ventilation installations.

Table 2 shows the results of comparing the efficiency of systems and fans.

It follows from Table 2 that the values of the coefficients of aerodynamic and energy efficiency of the supply systems are low.

Table 2. Calculation results of the ventilation systems energy efficiency.

Indication	**Equipment**	**Pressure**			**Consumption**		$V_{entr\ (ex)}$ **from bars**	***FSP***	η_{syst}	η_{fan}
		EP	***SP***	***ACP***	***L***		***V***			
		Pa	***Pa***	***Pa***	m^3/h	m^3/s	***m/s***	***W***	*%*	*%*
1	2	3	4	5	6	7	8	9	10	11
I -1	fan	363	580	363	11070	3.1	2.88	5500	21	73
central frame - panel conditioner - 10	motor									
	filter	146								
	air heater	56.5								
	air cooler	26.7								
I -2	fan	312	462	312	3100	0.9	2.88	1500	18.2	74
central frame - panel conditioner - 3,15	motor									
	filter	137								
	air heater	46.6								
	air cooler	27								
I -3	fan	363	580	363	11070	3.1	2.6	5500	20.5	73
central frame - panel conditioner - 10	motor									
	filter	146								
	air heater	56.5								
	air heater	26.7								
I -4	fan	312	454	312	3100	0.9	2.6	1500	18.1	74
central frame - panel conditioner - 3.15	motor									
	filter	137								
	air heater	46.6								
	air heater	27								

Continuation of the table 2

1	2	3	4	5	6	7	8	9	10	11
I -5	fan	227	426	227	9800	2.7	0.4	4000	15.5	71.4
entral frame - panel conditioner - 8	motor									
	filter	149								
	air heater	64								
central frame - panel conditioner - 8	motor									
	filter	149								
	air heater	64								
AV -1	fan GDR F-80-75	483	538	483	11175	3.1	1.74		56.1	83
	motor							3000		
AV -2	fan GDR F -80-75	483	538	483	11175	3.1	3.04		56.1	83
	motor							3000		
AV -3	fan GDR F -80-75	341	387	341	2550	0.7	2.88		50.2	81
	motor							550		
AV -4	fan GDR F -80-75	341	387	341	2550	0.7	2.88		50.2	81
	motor							550		
AV -5	duct fan	325	372	325	1090	0.3	3.24		31.4	73
	motor							361		
AV -6	duct fan	320	358	320	900	0.3	1.62		28.8	72
	motor							313		
AV -7	fan GDR F -80-75	400	464	400	9900	2.8	0.56		55.81	84
	motor							2200		

It follows from Table 2 that the values of the coefficients of aerodynamic and energy efficiency of the supply systems are low.

Table 3 shows the results of comparing the efficiency of systems and fans.

Table 3. Comparison of the efficiency of ventilation systems ηsyst, %, and their fans ηfan, %.

Indication	η, %		η_{syst} / η_{fan}
	System	Fan	
I -1	21	73	0.28
I -2	18.2	74	0.25
I -3	20.52	73	0.28
I -4	18.14	74	0.25
I -5	15.46	71.4	0.22
AV -1	56.06	83	0.68
AV -2	56.06	83	0.68
AV -3	50.18	81	0.62
AV -4	50.18	81	0.62
AV -5	31.43	73	0.43
AV -6	28.78	72	0.40
AV -7	55.81	84	0.66

5 Conclusions

Based on the results shown in Table 3, we can conclude that the average efficiency in the supply systems is at the level of 20-30%, due to the fact that they use a large amount of equipment, which increases energy costs and energy consumption. The average efficiency of exhaust systems is 40-70%, which is significantly higher than that of supply systems, since they do not have additional equipment except for filters in local exhaust systems.

Risks in the operating of technical systems are caused by the uncertainty of obtaining either the optimal expected result as an event, or its absence and non-occurrence of the expected event [1]. It is advisable to analyze and assess the risks of ventilation systems, in accordance with the provisions of the standard GOST (State standard) R ISO 9000-2015 "Quality management systems" in terms of comparing the planned quality indicators of ventilation systems and the resources used, that is, the ratio of efficiency and effectiveness [2, 3, 13].

At the same time, for optimal results, the ventilation system must provide and maintain the required technical characteristics during the operation.

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