ENERGY EFFICIENCY OF FANS FOR LOCAL VENTILATION

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Abstract: The report examines the issue concerning the energy efficiency of two fans for local airing. A theoretical and experimental study is presented.

Keywords: energy efficience, local ventilation, dead-end ventilation, forcing pipeline

Introduction

In underground mines, the forced local ventilation of blind workings is carried out by means of blowers. The blowers are manufactured in various sizes and speed of rotation. They are most often coupled directly to the motor shaft and are usually of axial flow type, with power between 4 and 110 kW and supply voltage of up to 1000 V. Their time of operation is within the range 20 – 24 hours per day. This is why their energy efficiency must be controlled and adjusted during their operation, which necessitates that the energy efficiency should be measured regularly.

Exposition

Objects of the present study are two blowers for local ventilation installed in a blind working and operating in air blowing mode. The blowers' main parameters are summarized in Table 1. The characteristics of the two blowers are presented in Fig.1 and 2. **[5,6]**

Table 1

Name of parameter	**Unit**	**Fans**	
Type		**CC 1254 Mk3**	**EVS 125-56-12**
Manufacturer		Clem Corp	EOL Vent
Output of electric motor	kW	55	75
Voltage	V	1000	1000
Electric motor speed	min^{-1}	1480	1480
Total pressure	Pa	25	36
Volume flow	m^3/s	1200	1400
Diameter of impeller	mm	1260	1250

The blowers for local ventilation are installed in the haulage workings, namely, 22nd and 33rd haulage galleries. These blind mine workings have a cross-section of 30 m^2. The ventilation ducts are made of rubber with a diameter of 1000 mm.

The blower type CC 1254 Mk3 ventilates the section from level 170 to level 150. The duct length is 300 m and is constructed as a double pipe with a diameter of 2×1000 mm.

The blower type EVS 125-56-12 ventilates block X level 170. The length of the ventilation duct is as follows: from the blower to the block approach – 95 m double pipe with a diameter of 2×1000 mm. In the block the duct branches into two – 30 m with a diameter of 1000 mm to the left, and 165 m with a diameter of 1000 mm to the right.

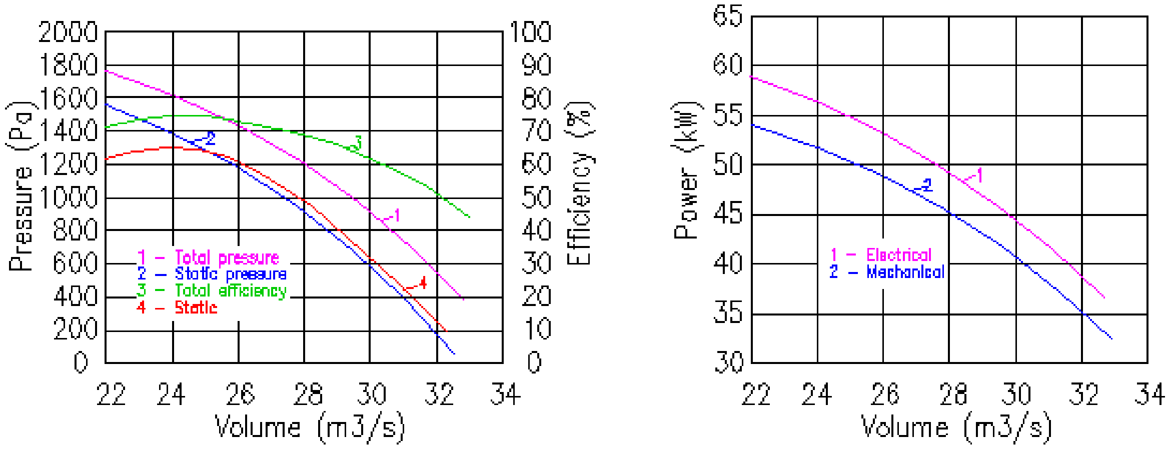

Fig. 1 Characteristics of blower type CC 1254 Mk3

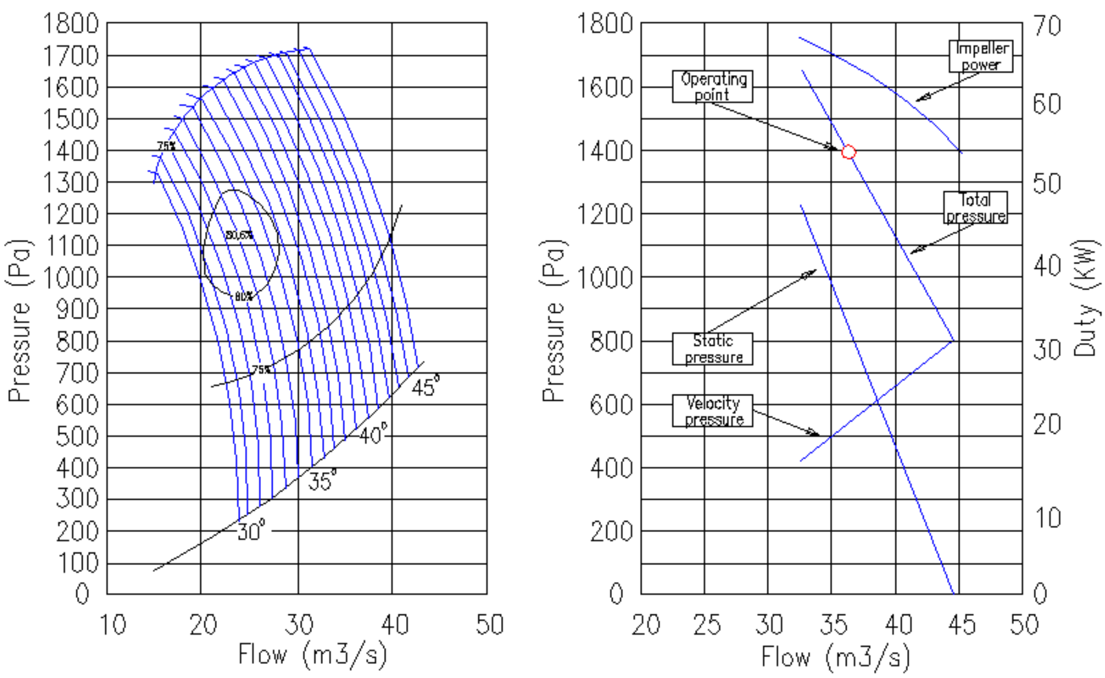

Fig. 2 Characteristics of blower type EVS 125-56-12

Methodology for determining the amount of air required to ventilate the blind working [1,2]

I. Calculation of the amount of air necessary to ventilate the blind mine working

1. Calculation of the required ventilation flow with respect to the factor of dust dilution and removal

- Calculation by using the optimal speed:

$$Q_d = Uopt * S = 0,6 * 30 = 18\ m^3/s \tag{1}$$

Q_d – flow required for dilution and removal of the dust aerosol;

$Uopt$ – optimal ventilation flow speed required for dilution and removal of the dust aerosol formed, $Uopt = (0,5 \div 0,7)\ m/s$ for blind mine workings;

$S = 30\ m^2$ – effective cross-section of the mine working, m^2.

- Calculation with respect to dilution in the case of known amount of dust formation in the mine working:

$$Q_d = \frac{q_d}{n - n_{in}} = \frac{10}{2 - 0,25} = 5,7 m^3/s \tag{2}$$

q_d – dust formation in the blind mine working, mg/s;

n – permissible dust loading of the air, mg/m^3 (n = 2 mg/m^3);

$n_{in} = 0,25 mg/m^3$ – dust loading of the inlet ventilation flow, mg/m^3

2. Calculation of the required ventilation flow with respect to the factor of explosive gases dilution and removal

$$Q_{eg} = \frac{7,8}{\tau}\sqrt[3]{A * S^2 * L^2} = \frac{7,8}{2000}\sqrt[3]{12 * 30^2 * 300^2} = 3,86\ m^3/s \tag{3}$$

L – length of the forcing pipeline, m

A – amount of explosive for a single explosion, kg

τ – time for blind working ventilation, s

3. Choice of the required flow for blind working ventilation

The required ventilation flow is the maximum value of all ventilation flows with respect to the separate factors:

$$Q_{rvf} = \max(Q_d, Q_{eg}) \tag{4}$$

4. Verification of the flow chosen for ventilation of the blind working with respect to the minimum and maximum speed of air flow motion in mine workings.

$$U_{max} * S \geq Q_{rvf} \geq U_{min} * S \tag{5}$$

U_{max} – maximum permissible speed of air flow motion, m/s;

- for mining and preparation workings U_{max} = 4 m/s

U_{min} – minimum permissible speed of air flow motion, m/s.

- for mining and preparation workings U_{min} = 0,25 m/s

- for workings with silicosis hazard, with effective gallery cross-section

$$(S \le 7\ m^2 \rightarrow U_{min} = 0{,}5\ m/s),\ \text{for}\ (S \ge 7{,}0\ m^2 \rightarrow U_{min} = 0{,}3\ m/s)$$

$$4*30 \ge 18 \ge 0{,}3*30 \Rightarrow 120 \ge 18 \ge 9 \qquad (6)$$

Since the above inequality (6) holds true, the chosen required ventilation flow Q_{rvf} is accepted as final.

II. Aerodynamic calculations of the forcing pipeline

1. Determination of the aerodynamic drag of the forcing ventilation pipeline

$$R_{vp} = 6{,}5*\frac{\alpha_p * L}{d_p^5} = 6{,}5*\frac{0{,}0015*300}{1^5} = 2{,}92\ \ kg/m^7 \qquad (7)$$

where:

R_{vp} – aerodynamic drag of the ventilation pipeline, kg/m^7

α_p – aerodynamic drag coefficient of the ventilation pipeline, kg/m^3

d_p – ventilation pipeline diameter, m

L – length of the forcing pipeline, m

Table 2 Aerodynamic drag coefficient value

Metal pipeline		Tarpaulin pipeline	
d_p, mm	α_p, kg/m^3	d_p, mm	α_p, kg/m^3
1000	0,0025	1000	0,0015

2. Determination of the air motion speed in the forcing pipeline

$$U_p = \frac{4*Q_{rvf}}{\pi * d_p^2} = \frac{4*18}{3{,}14*1^2} = 22\ \ m/s \qquad (8)$$

where:

U_d – air motion speed in the pipeline, m/s

d_t – pipeline diameter, m

3. Determination of the pressure loss in the forcing pipeline

$$W_p = R_{vp} * Q_{rvf}^2 + 0{,}5*\rho*U_p^2\ \ Pa \qquad (10)$$

where:

W_p – pressure loss, Pa

$\rho = 1{,}2\ kg/m^3$ – air volume density

In superposition, the characteristics of the ventilation system with the characteristics of the fan, the intersection is (Q = 28 m^3/s, H = 1200Pa). Using the same characteristics the efficiency η = 0,68 and P = 49 kW is calculated.

The results from the calculations of the second fan type DVS 125-56-12 for local ventilation are:

- Calculation by using the optimal speed: $Q_d = 36 \text{ m}^3 / \text{s}$;
- Calculation with respect to dilution in the case of known amount of dust formation in the mine working: $Q_d = 5{,}7 \text{ m}^3 / \text{s}$;
- Calculation of the required ventilation flow with respect to the factor of explosive gases dilution and removal: $Q_{eg} = 5 \text{ m}^3 / \text{s}$;
- Choice of the required flow for blind working ventilation: $Q_{rvf} = 36 \text{ m}^3 / \text{s}$;
- Determination of the aerodynamic drag of the of forcing ventilation pipeline; $R_{vp} = 0{,}81 \text{kg} / \text{m}^7$;
- Determination of the air motion speed in the forcing pipeline: $U_d = 45{,}8 \text{m/s}$

In superposition, the characteristics of the ventilation system with the characteristics of the fan, the intersection is (Q = 36 m^3/s, H = 1380Pa). Using the same characteristics the efficiency η = 0,76 and P = 66 kW is calculated.

Experimental measurements

The following complex of measurement devices was used in order to determine the actual parameters of the ventilation equipment installed in the blind mine working:

Vernier Lab Quest 2 **-** standalone interface for collecting sensor data with its built-in graphing and analysis application;

ANM-BTA **-** anemometer for measuring air flow speed;

BAR-BTA **-** barometer for measuring and monitoring atmospheric pressure;

Testo 735 **-** electronic multi-channel temperature measuring instrument;

FLUKE 430 **-** three - phase power quality and energy analyzer;

Fluke i400s AC **-** current clamp.

The measurements were performed following the methodology described in **[3,4]**

The pressure measurement was carried out in an artificial opening at the blower outlet.

The air flow speed was measured at a distance of 10 m away from the blower. The measurements' duration was about 10 min. The averaged values are presented in tables 3 and 4 for blowers with power 55 kW and 75 kW, respectively.

Table 3

CC 1254 Mk3 - 55kW					
Time (min)	Pressure (Pa)	Speed (m/s)	Active Power (kW)	Voltage (V)	Power Factor
0	856,6	29	46,4	1020	0,83
1	856,7	29,1	46,3	1020,2	0,83
2	856,8	29,2	47	1019,9	0,83
3	856,9	29,3	47,1	1019,4	0,83
4	857	29,4	46,9	1019,2	0,83
5	857,1	29,6	46,8	1019,5	0,83
6	857,2	29,7	46,7	1019,3	0,83
7	857,3	29,8	46,8	1019,7	0,83
8	857,4	29,9	46,9	1019,7	0,83
9	857,5	30	47	1019	0,83
10	856,6	29	47	1018,8	0,83
average	**857**	**29,5**	**47**	**1019,5**	**0,83**

Table 4

EVS 125-56-12 - 75kW					
Time (min)	Pressure (Pa)	Speed (m/s)	Active Power (kW)	Voltage (V)	Power Factor
0	1319,8	36,8	62,7	1028,4	0,82
1	1319,5	36,5	62,5	1028,3	0,82
2	1320,5	36,9	62,6	1026,9	0,82
3	1319,7	36,7	63,9	1026,3	0,82
4	1319,6	37,2	62,5	1026,7	0,82
5	1319,9	37,5	62,6	1028,1	0,82
6	1320,8	37,3	62,8	1029,3	0,82
7	1319,6	37,7	63,6	1029	0,82
8	1320,7	36,8	62,9	1025,7	0,82
9	1319,9	36,9	63,7	1023,8	0,82
10	1319,8	36,8	62,8	1023,2	0,82
average	**1320**	**37**	**63**	**1026,8**	**0,82**

Conclusions and recommendations on the fan type CC 1257 Mk3:

- The choice of fan is not appropriate. The required flow of air is almost 64% larger than necessary;
- The efficiency of the used fan for local ventilation in this mode is 10% lower than the calculated value;
- The use of a new fan with appropriate characteristics is recommended - namely, one with optimal flow rate of 18-20 m3 / s and pressure of about 1000 Pa - i.e. local fan ventilation with the possibility of adjustable parameters (change of the angle of the blades) - available as a model CC 1070.

Conclusions and recommendations on the fan type EVS 125-56-12:

- Due to the impossibility to complete the measurements of the distribution of air flow (since the working process will be violated) a single measurement of the air speed at the outlet of each of ventilation tubes was done.
- Leveling of the air by placing additional resistance in the duct 1 (partial barrier) is necessary.

These measurements prove that the right choice of fan for local airing has been made. The differences in aerodynamic drag are considerable. In this case it is logical for the ventilation flows to be distributed unevenly.

Differences in flow rate 23 + 12,3 = 35,3 m^3/s are not equal to 37 m^3/s. These are losses from seepage.

The results from the measurements and the calculated values for flow fan show that fan 1 is not sized properly. Selection of a new type of fan is recommended.

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