Investigation of the noise reduction effect of ventilating systems

Vitaly M. Kolykhalin
cap-007@mail.ru

Abstract

The well known magnetostrictive effect of electric motors results the non-linear dependence of magnetic noise components in the wide sound range from infrasonic frequencies. In the open ventilating pipe the electric motor with the fan impeller and the fan impeller without the electric motor on a quarter length wave distance of electric network frequency are installed. On the same distance the same series identical a pair of elements is set up but two electric motors on half length wave distance of electric network frequency are fixed and through the phase-shift device are switched on. The compensatory effect of the basic component of magnetic electric motor noise is considered. The theoretical and experimental data of the ventilating systems noise reduction are commented on.

1 Formulation of the problem of the reducing magnetic fan noise component

Increasing application of power electronics on transport, manufactures, home equipments and as a matter of fact growing up low-frequency and infrasonic fluctuations were taken care of by investigation methods and techniques for human audition protection. It is common observation that monaural personal threshold of audibility for sound fluctuations with 1 Hz frequency is coincident with listening pain barrier for acoustic pressure 140 dB. Such low person acoustic sensitivity in infrasonic range is masked by greater person sensitivity in the average frequencies. The infrasonic makes an attacking on the human health by emotional and biological influences. A person surface by infrasonic fluctuations through air, body and bone conductivity is affected [1].
Not expensive asynchronous electric motors with such basic noise components as magnetic, mechanical and aerodynamic in the conditioning and typical ventilation systems are used.
The aerodynamic noise components such as air interaction cores of a rotating rotor with a stationery stator, motor construction and a number of its ventilation blades are consist on. The intensity of such noise is growing up with increasing motor size and speed of rotation. Strong ventilation noise in low-frequency and infrasonic

range has the tendency of decrease 5 dB on an octave with frequency increase and a centrifugal force is made by.

Without taking into account executive mechanisms a mechanical component of motor noise also is depended on out-of-balance rotor, deformation of winding and rotor elements which really inertia, friction and heating are caused by. As well transitive effects of a rotor with a rotation stator asynchronous electromagnetic field and transformation its fluctuation into stator windings as infrasonic modulations is taken notice of.

As a whole the mechanical component of fan noise is less effective then other because of the smaller radiation areas, difference wave resistances in air and vibrating elements are turned out.

Noted noise components are brought about electrodynamic, electromagnetic and magnetostrictive forces a power electromagnetic field formed. Radial ring plates of stator electrotechnical steel are deform by a magnetostrictive Fms force taking place under working alternative magnetic field. Force lines of alternative magnetic field on circles with the centers on an axis of rings are settled down.

Peak value of these forces as time depended functions B_{mi} is proportional to a square of stator voltage U_{mi} and is founded from the ratio [2]

$$F_{mc} = \pi a_i S_{st} B_{mi}^2 = \pi a_i S_{st} \left(\frac{U_{mi}}{n\omega_i} \right)^2 \quad (1)$$

where $S_{st} = (R_{ex} - R_{in})h$ is the sectional area of magnetic core R_{ex} and R_{in} is accordingly external and internal radiuses, h is the length of magnetic core); $_i$ - the magnetostrictive constant of steel; ω_i is the angular frequency of fluctuations.

The aerodynamic noise is known to prevail in the average and high frequency ranges when an impeller with typical asynchronous electric motor is a basic source. The aerodynamic and mechanical motor noise components are carried on by magnetic noise component on frequency 50 Hz.

For the magnetic component carried on to reduce there must be method including the effect called as standing wave barrier. The standing wave barrier is formed into pipe on frequency 50 Hz of the basic tone and its harmonics.

The fan sound energy is reduced by dissipative losses, outflow of energy through walls and by reflection from obstacles into ventilation pipe.

The first part of source sound energy is radiated from the waveguide aperture in the form of running sound waves. Having been reflected from passive impeller by reason of jumping of acoustic resistance the other part of source sound energy was spent on formation reverberation sound field into pipe.

Then the sound energy outside radiated from the waveguide aperture is summarized two components: the running sound waves and the component of reverberation sound field. In order to reduce the last one a pair of identical impellers (with motor and without one) should be installed on the distance of half-wavelength due to frequency electric network 50 Hz between them. This procedure is necessary to formation standing sound waves in a pipe.

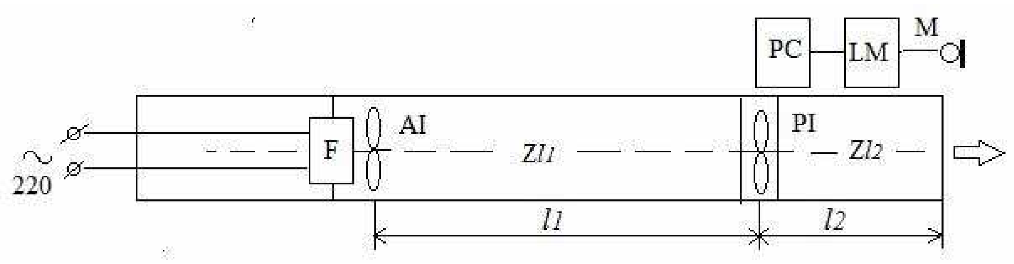

Figure 1: Installation diagram of elementary standing wave barrier

2 Elementary standing wave barrier

The special acoustic room in St. Petersburg State Cinema and Television University enables measurements to be carried out without external noise sources. The measuring installation consisting of the round metal pipe with length 4 m, diameter 0,1 m, thickness 0,004 m, the single-phase electric motor F (100 Wt) with the impeller AI and the passive impeller PI on the support isolated from the pipe wall by rubber are given in Fig.1. This apparatus for estimation of the standing wave barrier effect by microphone M102 and sound level meter RFT0024 are applied.
The distance l_1 between impellers AI and PI on half-wavelength due to frequency electric network 50 Hz is installed. It is impotent that PI from the waveguide aperture on distance l_2 quarters-wavelength due to frequency 50 Hz is settled down. Impellers AI and PI for blowing out of a gas stream are used and at the same time like big resistances for sound waves are happened.
The expression for entrance mechanical resistance is

$$Z_m = Z_s + Z_{l_1} + Z_{l_2} \tag{2}$$

where Z_s is the entrance mechanical resistance of the fan source; Z_{l_1} is the air resistance in the pipe interval l_1; Z_{l_2} is the air resistance in the pipe interval l_2.
Provided $f_s = (2n+1)c_0/2l_1$, $n = 0$ the entrance mechanical resistance for two pipe sides closed on the interval l1 will be in the form:

$$Z_{l_1} = -j\rho_0 c_0 S \cot kl_1 = -j\rho_0 c_0 S \cot \pi \tag{3}$$

where ρ_0 is a specific density of air; c_o is a sound speed; S is an area of cross-section of a pipe; $k = 2\pi f/c_0$ is a wave number.
Provided $f_s = (2n+1)c_0/2l_1$, $n = 0$ the entrance mechanical resistance for the waveguide aperture on the interval l_2 will be in the form:

$$Z_{l_2} = j\rho_0 c_0 S \tan kl_2 = j\rho_0 c_0 S \tan \frac{\pi}{2} \tag{4}$$

If the l_1 and l_2 have absolutely rigid boundary conditions the values Z_{l_1} and Z_{l_2} will tend to infinity. However fan impellers are represented the impedance boundary conditions that make it difficult enough to analyze analytically the effect of standing

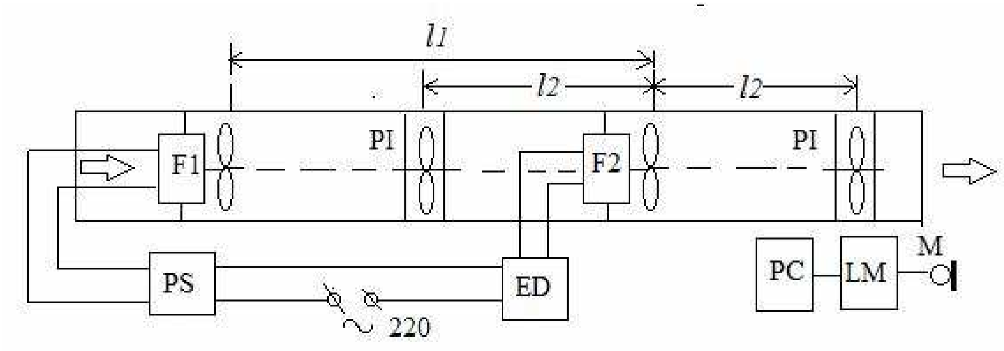

Figure 2: Installation diagram with standing wave barriers and the negative correlation effect

waves barrier but might be it possible in next paper. If the AI is moved from the PI along pipe on the distance up to 3,44 m between impellers then the sound pressure at waveguide aperture will be changed. So the standing wave barrier using half-wavelength due to frequency electric network 50 Hz effect is illustrated in Fig.1 to reduce the noise pressure at the pipe outlet on 6 dB in the broadband range from 16Hz to 10000Hz.

3 Joint action the standing wave barriers with the negative correlation effect

In the pipe two acoustic effects for reducing electric motor noise on the basic frequency 50 Hz and coincidence harmonics was realized: the effect of standing waves barrier and the negative correlation effect between antiphase amplitudes of acoustic noise pressure a pair of fan electro motors. The first effect in this paper is illustrated. The second effect in the previous paper was investigated [3].

It is impotent to make a few remarks concerning last one. In solving the decreasing electric motor noise problem in a short pipe closed it was necessary to install a pair of identical single-phase electric motors F1 and F2 at opposites into a pipe. The system of standing and pseudo-standing waves on frequencies of the basic tone 50 Hz and other components was excited by the motors. F1 and F2 influence the flat sound wave excitations as pulsing cylinders and as an interference result of the negative correlation effect on the basic frequency 50 Hz and coincidence harmonics was registered.

The same installation of the electric motors F1 and F2 but for ventilation system with the long pipe both sides opened was used. A pair of identical single-phase electric motors installed on half-wavelength distance due to frequency 50 Hz with the passive impeller PI between them are shown in Fig.2. As F1 as F2 with the passive impeller PI on a quarters-wavelength distance due to frequency 50 Hz are turned out.

For a correlation effect on the basic frequency 50 Hz to exist there must be two objects involved in the motor electric supply: phase shifter PS and electric delay ED.

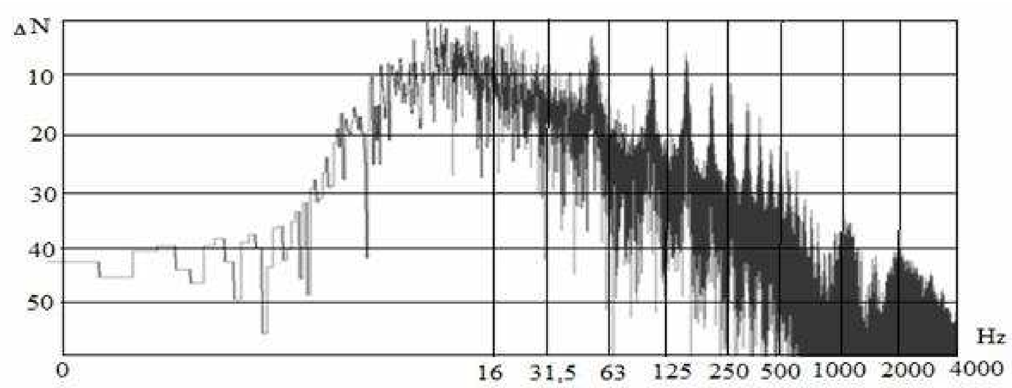

Figure 3: Noise spectrogram with two identical motors and identical impellers excluding the standing wave barriers and the negative correlation effect

In operation mode the network signal goes to the electric delay line ED (Fig.2) and the phase shifter PS. Electricity for the motor F1through phase shifter with lagging 90 degrees against the motor F2 is supplied. After interval $\tau = l/c$ (l is the distance between motors) the acoustic process into the pipe arrives at the motor F2. But on the same time the electricity for supplying F2 through the electric delay is delayed. For estimation of the pressure by microphone M and sound level meter LM are applied.
In order to find out affectivity of the fan noise reducing methods the experiment data due to scheme in Fig.2 and the same scheme but apart from the electric delay line ED, the phase shifter PS, installation motors and impellers in position were standing wave barrier effects working should be compared.
The noise spectrogram using two identical motors and two identical impellers excluding any standing wave barriers and the negative correlation effect into the ventilation pipe is illustrated in Fig.3.
The frequency on abscissa (Hz) and the relative acoustic pressure on ordinate axis are constructed.
The noise spectrogram using two identical motors and two identical impellers including the some standing wave barriers and the negative correlation effect into the ventilation pipe is illustrated in Fig.4. The noise spectrogram commenced on affectivity of the reducing the basic frequency 50 Hz and coincidence harmonics are shown.
The frequency on abscissa (Hz) and the relative acoustic pressure on ordinate axis are constructed. The reducing fan noise pressure on 13 dB in broadband range by the negative correlation effect and the standing waves barriers effect are obtained.

4 Results

It follows that the standing waves barriers effect help us to reduce fan noise pressure at the pipe outlet on 6 dB in broadband range from 16 Hz to 10000 Hz when this data is fixed by the sound level meter. The negative correlation effect makes it possible to obtain reducing fan noise pressure on 7 dB not only reducing sound fluctuations with frequency electric network 50 Hz but also in low-frequency and infrasonic

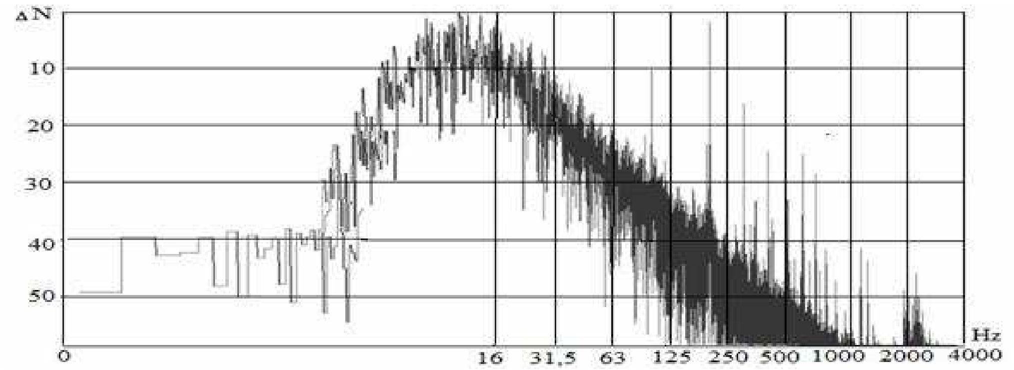

Figure 4: Noise spectrogram with two identical motors and identical impellers including the standing wave barriers and the negative correlation effect

range. Such low-frequency and infrasonic fluctuations are excited by transformation asynchronous electromagnetic fluctuations into stator windings as infrasonic modulations and modulation electromagnetic distortions. One must expect that reducing fan noise on transport, manufactures and home equipments will be taken care of by using the standing waves barriers with the negative correlation effect for human audition protection.

References

[1] GOST P 51401-99. Acoustics. Definition of sound power levels of noise sources with sound pressure. - M.: Gosstandart of the Russian Federation, 1998.

[2] Kolykhalin V.M., Davydov V.V. Device of the electric motor noise compensation. Patent of the Russian Federation є2528552, M. Federal serv., RU RU 2528552 C1, published 20.09.2014 Bul. 26.

[3] Davydov V. V., Kolykhalin V. M. About compensation method of the electric motor noise.- B.: Vestnik BGTU named after V.G. Shukhov (2), 2014.

Lenynskiy pr., 95, korp.2, 403, 198330,St.Petersburg, Russia, cap-007@mail.ru