Adjustment for decrease of magnetic motor noise

Vitalij M. Kolykhalin

cap-007@mail.ru

Abstract

The electric motor inside volume formed by the winding stator and several rotor core elements is considered. Electromagnetic interaction between stator field winding and the rotor field winding, mechanical motor vibrations and air fluctuations from ventilation motor impeller excite the basic components of air noise in a wide frequency range. Magnetostrictive forces causing radial deformation of the stator core rings under alternate field action bring the special addition in motor noise. The dependence of the sound noise pressure from electromagnetic vibrations inside of the small volume chamber SVC is considered. The greatest linear size SVC less than half of wave length of the longest eighen frequency is installed. The construction of the stator core of the alternate bipolar commutator motor having two acoustic channels with determinate diameters in the center of each magnet poles is shown. Except of external surface stator core fluctuations there are two acoustic sources excited by internal surface stator core and influence through two channels in antiphrasis according external surface stator core fluctuations into SVC. The effective decrease of the carrying basic 100 Hz frequency magnetic motor noise is carried out. The method of the equivalent generator for symmetric parts in the electric analogue scheme is advanced. Equivalent generators as two sources of acoustic fluctuations switched on towards each other are described. The spectrograms illustrating of magnetic motor noise decrease are shown and the adjustment for decrease of magnetic motor noise is supported.

1 Formulation of the problem of the low frequency electric motor noise reducing

Perfection of acoustic measurement technique in low sound and infrasonic frequencies, development of person protection methods from detrimental of health are very importance as far as increasing functions of power transport and manufacture electronics.

Infrasonic fluctuations with long wavelength influence on all person surfaces by air, body and bone conductivity with loss of natural localization on a source.

Electromagnetic interaction between electric motor stator and electric motor rotor, mechanical external and internal vibrations and air rotation fluctuations excite the

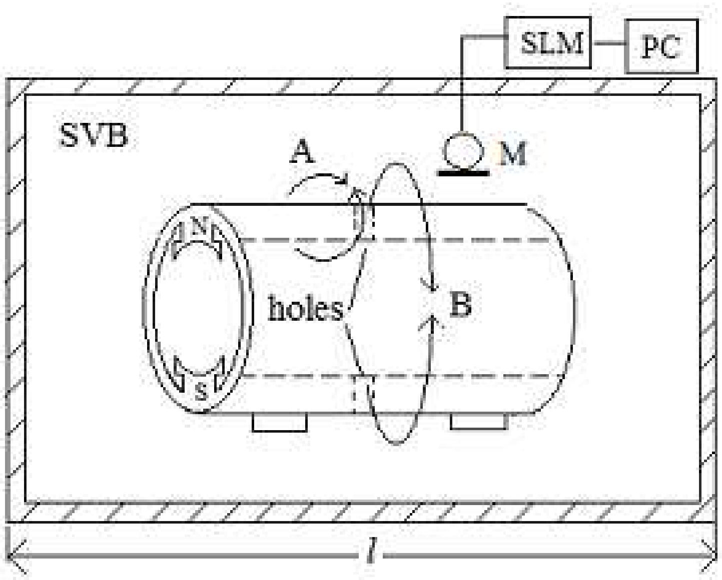

Figure 1

basic components of air noise in a wide frequency range [1]. It is essential the transition effects of motor slip and transformation of rotor core fluctuations bring appreciable spectral distortions in low sound and infrasonic frequencies.

The greatest distribution in power technical equipments with asynchronous motors and commutate alternating current motors with magnetic, mechanical and aerodynamic noise components have been received.

The magnetic motor noise components depending on stator core vibrations in the small volume box (SVB) with the maximal size no more than half of air wave length corresponded the double frequency network 100 Hz are investigated. Such SVB for graduation of measuring microphones, for estimation of sound insulation of small cabins and the casings damping noise by full or partial shielding of sources are applied.

The stator fluctuations by the electromagnetic forces are excited. During each half of a cycle of alternative electrical field the stator core as one compression - stretching cycle is deformed. The doubling network frequency corresponding of mechanical fluctuations 100 Hz is prevailed.

The sound pressure motornoise depended on motor force vibrationinto closed volume SVB from Poisson equation are found

$$p_m = \frac{\gamma P_0 Q_H}{V l_k} \int_0^{l_k} \xi_m \cos kx dx = \frac{p_m \sin k l_k}{k l_k}, \tag{1}$$

where $\gamma = 1{,}4$ is the adiabatic constant; P_0 is atmospheric pressure; x is the coordinate of SVB length l_k; k is the wave number, c is the sound speed in air, Q_H is the stator core external area.

Thus process as statistical is considered when the level of sound pressure is the same in all points of the SVB and does not depend on coordinates. It is exact restriction for infrasonic and low frequencies while eighen frequencies of the SVB considerably above frequencies investigated are excited [2].

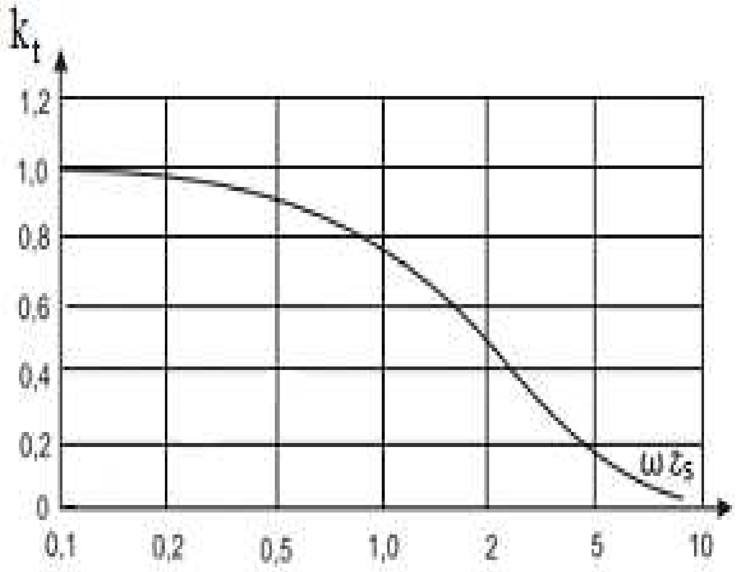

Figure 2: The SVB installation: N, S – the stator magnetic poles; SLM - the sound level meter; PC - the computer; M - the microphone; A - the acoustic short circuit effect; B - the negative correlation effect

An electric motor widely using in electric tools (for example drills), household appliances (washing machines) for research of motor noise was taken.
The installation for analysis of magnetic noise reduction including the SVB with the linear sizes 0,4m 0,5m 0,6m; the microphone with the amplifier; the sound level meter; the computer and the single-phase alternative current collector electric motor 800 Wt was developed (Fig.1).
All electric inputs into SVB and its cover during the measurements as much as possible were encapsulated and the electrical motor by the rubber damper was installed.

2 Effect of acoustic short circuit

The effect of acoustic short circuit for calculation of loudspeaker enclosure is well known. The alternative air compression and air stretch by opposite surfaces induction loudspeaker diaphragm are created. For example when sound pressure on the forward surface loudspeaker diaphragm is increased than one on the back surface is decreased. If loudspeaker acoustic baffle is absent the effect of acoustic short circuit on low frequencies is happened because of the diffraction of sound waves. The result sound pressure in surrounding space is decreased (Fig.1 curves A).
The similar acoustic effect to reduce of low frequency electric motor noise is applied. For study of the efficiency factor of motor noise reduction the basic magnetic noise component with carrying frequency 100 Hz in broadband spectrum of pressure is examined.
The air capacity inside of the electric motor in the form of volume formed by winding stator and rotor elements is considered. One hole with profile s through the stator core as the acoustic channel for passing internal sound fluctuations was drilled.

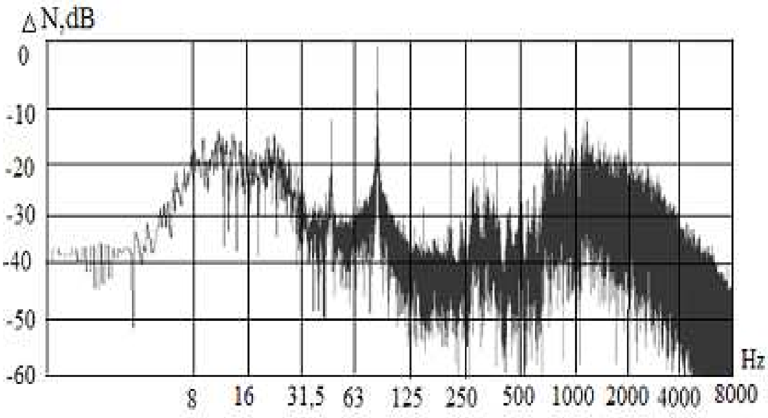

Figure 3: Frequency dependence between acoustic channel pressure and motor core external pressure

The passing internal sound fluctuations summarizing with antiphase stator external sound fluctuations are resulted. Then motor noise pressure into SVB as result of the interference of internal and external stator core fluctuations is decreased.
For example when motor internal air pressure by compression of stator core fluctuations is reduced then some air enters through the hole into motor. In the one hand the pressure work for this process as product of force on a way $uPs\Delta t$ is expressed. On the other hand the pressure into SVB is reduced and the work of the force for this process is $V\Delta P$. Then next equation is taken

$$uPs\Delta t = -V\Delta P, \tag{2}$$

were u is the speed of sound fluctuations, s is an area of hole, V is volume of SVB and P is acoustic pressure.
Passing to limit the equation (1) is presented

$$uPsdt = -VdP. \tag{3}$$

The common decision of the equation (3) after integration is shone

$$p = Ae^{-\frac{us}{V}t}, \tag{4}$$

were A is a constant of integration.
Other conditions being equal the noise pressure into SVB is summarized with external stator core pressure P_{ex} and some adding pressure of an acoustic channel

$$P_{SVB} = P_{ex} + Ae^{-\frac{us}{V}t} \tag{5}$$

The pressure into SVB changing under some law for example harmonious is considered

$$P_{SVB} = P_m \cos \omega t. \tag{6}$$

For simplification of the analysis the oscillating stator core as identity headphone diaphragm exciting flat sound waves is represented. Substituting (6) in (3) the

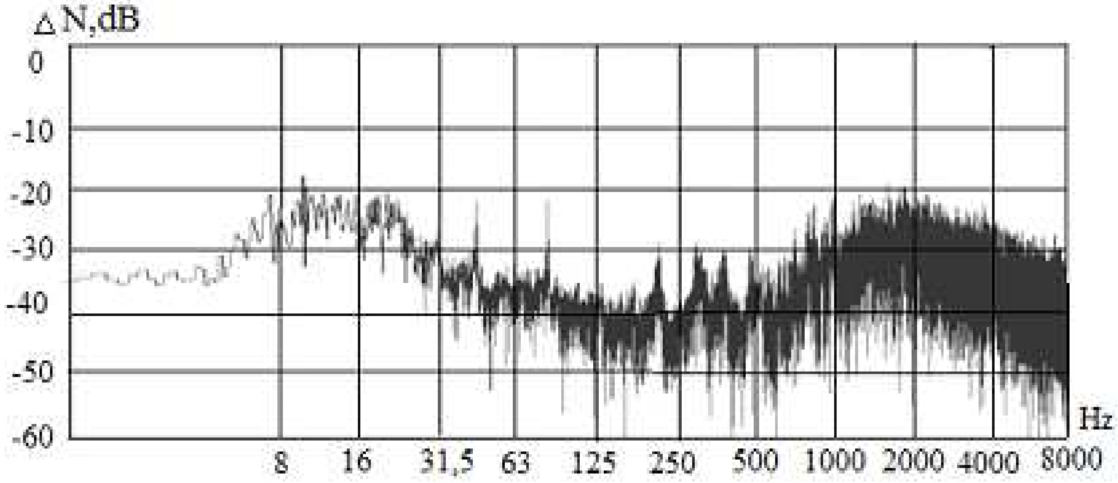

Figure 4: Noise pressure spectrogram for motor with a pier of stator core holes

differential equation having intensity in right part of the equation as the power characteristic of sound field is obtained:

$$usP_{SVB} + V\frac{dP_{SVB}}{dt} = uP_m \cos\omega t. \tag{7}$$

The decision in general view is represented in the form

$$P_{SVB} = p_m \cos(\omega t - \varphi) + Ae^{-\frac{us}{V}t}, \tag{8}$$

where A is a constant of integration, p_m is pressure in the acoustic channel, $PSVB$ - pressure into SVB.
The values of p_m and φ can be obtained as

$$p_m = P_m/\sqrt{1 + (\omega V/us)^2}, \varphi = arctg(\omega V/us). \tag{9}$$

If data about of the acoustic channel and the SVB is determined then preview equations can be found out finally but the product $\omega V/us$ especially if an equation for volumetric speed in the acoustic channel for laminar stream (the law Hagen-Poiseuille) is used in the form

$$u = \pi a_k^4 \Delta P/8\mu\lambda_k \tag{10}$$

and also ratio for active component of viscous friction in the channel reduced to area of diaphragm Sd is represented

$$r_c = 8\mu\lambda_k S_t/\pi a_k^4, \tag{11}$$

where a_k and λ_k are the radius and the length of the acoustic channel accordingly and μ is the air dynamic viscosity coefficient.
Then product $\omega V/us$ can be received in the form

$$\omega V/us = \omega c_f r_c = \omega\tau_s, \tag{12}$$

where cf is the air flexibility into SVB, ω is frequency of acoustic fluctuations and τs is a time constant of the system: channel - SVB or it is the acoustic low frequency filter.
The transfer coefficient of the acoustic channel kt into SVB can be found in the form

$$k_t = p_m/P_m = 1/\sqrt{1 + (\omega\tau_s)^2}. \tag{13}$$

The frequency dependencies k_t in Fig.2 is shown.
The greatest effect of mutual antiphase compensation between the acoustic channel fluctuations and external motor core fluctuations at small $\omega\tau_k$ is shown in Fig. 2.

3 Negative correlation effect between two acoustic stator core channels

The construction with two opposite holes drilled through bipolar stator core as one in each magnetic pole has more effective result.
For discussion about effect of negative correlation method there are two motor noise pressure spectrograms into SVB: without stator core holes (Fig.3) and with a pier of stator core holes as two acoustic channels (Fig.4).
The frequency on abscissa (Hz) and the relative acoustic noise pressure (dB) on ordinate axis are constructed. The integrate level noise pressure 88 dB by the sound level meter $RFT0024$ was fixed. The maximum noise pressure value is corresponding of the basic magnetic motor noise frequency 100 Hz.
The frequency on abscissa (Hz) and the relative acoustic pressure (dB) on ordinate axis are constructed. The integrate level noise pressure 81 dB by the sound level meter $RFT0024$ was fixed. There are two effects of motor noise reduction in Fig.3: the acoustic short circuit (Fig.1 curves A) and the negative correlation effect for the frequency 100 Hz and first harmonics (Fig.1 curves B).

4 Analysis of the magnetic noise reduction effects

From comparison of spectrograms in Fig.2 and in Fig.3 the reducing motor noise pressure on 20 dB for the basic magnetic motor noise frequency 100 Hz is fixed. Integrate level pressure from 88 dB (without acoustic channels) to 81 dB (with acoustic channels) in wide strip is decreased.
As follows from stated the effective method developed making quieter electric motors for person protection in low sound and infrasonic frequencies and increasing functions of power electronics on transport is provided.

References

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