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NOISE OF AUTOMOBILE ALTERNATOR

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1. INTRODUCTION

The noise in the passenger compartment of an automobile is caused by various sources inside and outside of the automobile. The alternator can be one of the sources of acoustic annoyance, particularly when the car is at a standstill and the engine is operating at no-load speed (low revolutions).

The noise of an automobile alternator is caused by ventilation airflow, rotating mechanical components, and fluctuating magnetic forces. Magnetic forces, which are proportional to the square of the flux density, produce magnetic noise. This magnetic noise has characteristic tonal components in the frequency range of 800 Hz to 3 kHz. The approach taken in this paper was based on vibration and sound pressure measurements of the stand-alone alternator under loaded and unloaded conditions.

The generation of magnetic noise can be explained as follows. Magnetic flux density in the air gap results in magnetic forces of various directions. The directions and amplitudes of these forces depend on the geometry of the air gap, saturation, and other factors. As the rotor rotates, the variation of magnetic flux causes strong periodic forces which act on the rotor and stator. Since the rotor is significantly sturdier than the stator, periodic forces excite the stator, resulting in significant vibration. If both the rotor and the stator have slots parallel to the axis of rotation, the strongest magnetic forces will be in the radial direction, with amplitude proportional to $B^2 / 2\mu$, where μ is the permeability of air. The frequency of the forces is obviously dependent on the alternator revolutions; thus tone components in the frequency spectra are multiples (harmonic components) of revolutions per second. The frequency component which characterises an alternator is dependent on numbers of stator slots n_s and rotor slots n_r.

One of the major frequency components can be calculated by expression[1]:

$$f_m = \frac{N}{60} n_s , \qquad (1)$$

where N is the rotational speed in rpm. If this frequency corresponds to one of the modal frequencies of the stator the magnetic noise significantly increases.
One well-known way to reduce these forces is to change the shape of the rotor segments so that the rotor slots are not parallel to the stator slots. It results in a significant decrease of radial forces, but additional moments of force appear, which cause the rotor to vibrate in the axial direction.

2. MEASUREMENTS

Vibration measurements were conducted at the Acoustic Laboratory of the Department of Physics. The alternator was driven by an electric motor of 5 kW using a V-belt. Acceleration was measured using B&K 4332 accelerometers connected through a measuring amplifier to a PC 30 PGH plug-in card with AD converters. The measured data were processed using the Sound software developed at the Department of Physics. All measurements were done in the range of revolutions from 2000 to 3500 rpm, the range in which magnetic noise is significant. For revolutions greater than 3500 rpm, the magnetic noise is masked by the noise generated aerodynamicaly by the cooling fan.
As explained above, the alternator stator vibrates in radial and axial directions. Typical vibratory-acceleration levels in both directions are shown in Figure 1. Comparing measured results it is seen that the levels of radial vibrations are about 5 dB higher then the axial ones. Figure 2 shows corresponding sound pressure levels measured in distance of 50 cm.
Sound power and sound pressure measurements were conducted in the acoustically-adapted room at the Development Laboratory of Magneton Kroměříž. The alternator was driven by a dynamometer of 10 kW with continuously changeable revolutions. Both sound intensity and sound pressure were measured using a B&K 2145 analyzer with a B&K 3548 sound intensity probe.
To find the resonance frequencies of the stator, measurements of sound pressure spectra were taken for revolutions from 2100 to 3300 rpm with revolution step of 100 rpm. Figure 3 shows the results in two different representations. The main maximum is seen in the range from 1kHz to 2 kHz in good accordance with equation (1). Overall sound power levels are shown in Figure 4. It is seen that in this revolution range there are two maxima conected with resonace of the stator.

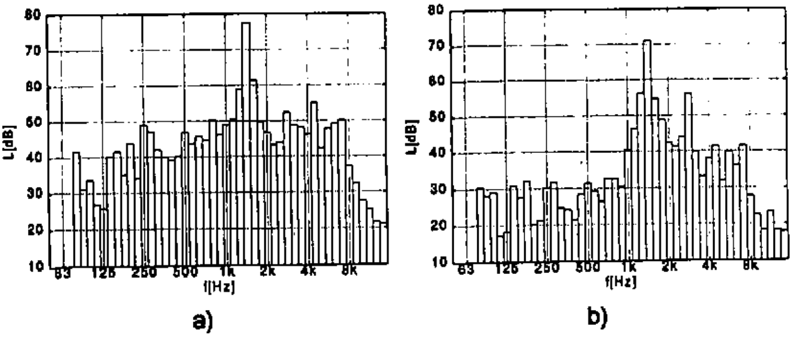

Fig. 1 - 1/6 octave vibratory-accelerated levels for 2500 rpm: a) radial direction b) axial direction

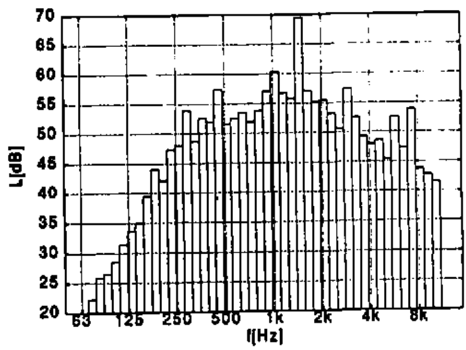

Fig. 2 - Sound pressure spectrum for 2500 rpm.

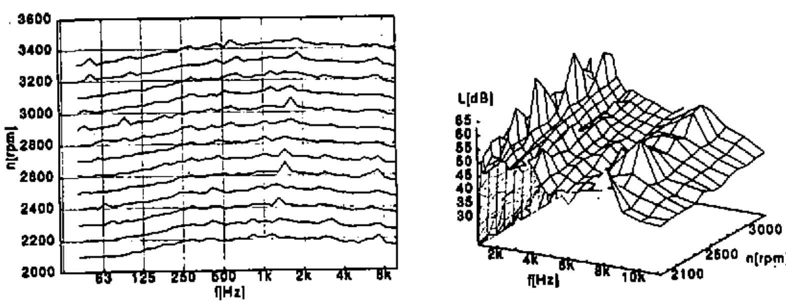

Fig. 3 - Frequency spectra of sound pressure levels for revolution range from 2100 to 3300 rpm.

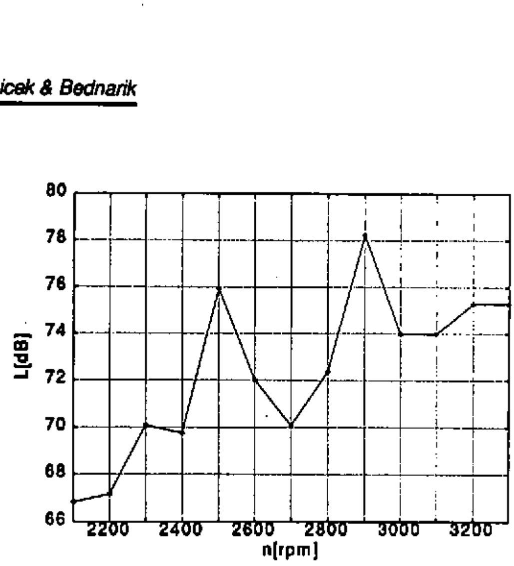

Fig. 4 - Overall A-weithed sound power levels measured according to ISO 9614-1.

3. CONCLUSIONS

Vibration and sound power techniques were used to measure magnetic noise of an automobile alternator. In measuring the noise parameters of the alternator, the appearance of the electromagentic noise was confirmed. The rise of the 36 harmonic above the rest of the spectrum is mostly visible in the range from 2500 to 3000 rpm. As stated above, the frequency of the tonal component of magnetic noise depends on rotor rovolutions. If this frequency approaches some of the modal frequencies the noise level considerably increases. To reduce the alternator noise, experiments based on reinforcing of the stator were performed with good results[4].

REFERENCES

[1] S.J. Suh, J. Chung, D. Lim, C.H. Hwang, Noise Source Identification of an Automobile Alternator by RPM Dependent Noise and Vibration Spectrum Analysis, Noise Control Eng. J. 37(1), p. 31-36 (1991).

[2] R.H. Lyon, Machinery Noise and Diagnostics (Butterworths, Boston, 1987)

[3] V. Hamata, Hluk elektrických strojů (Academia, Praha, 1987). (in czech)

[4] O. Jiříček, at al., Research report, HS 40-95023, 1995.