

Spectral analysis of acoustic car noise

P V Pchenitchnyi¹, V A Strekalov¹, R R Tagirov¹, R R Shaimukhametov¹

¹Kazan Federal University, Kazan, 420008, Russian Federation

pavel.pchenitchnyi@kpfu.ru

Abstract. The results of the Fourier spectroscopy of the acoustic noise of an internal combustion engine are presented. The sound was recorded using a voice recorder placed near the engine under varied operating conditions for the four-cylinder petrol engine. The distinctive characteristics of the periodograms were associated with the certain physical processes in the engine.

The sound field is determined by the various physical processes of the car engine. Extraction of useful information from acoustic data allows solving a number of applied problems, in particular, by the nature of acoustic noises to diagnose faults of the car [1], to identify the car by sound. An adequate model of noise makes it possible to improve the ergonomic parameters of the car, at the present time methods of active suppression in the car interior are being developed [2, 3].

The variety and interdependence of sources of acoustic noise causes a complex structure of the sound field. Nevertheless, the frequency of processes in the engine gives hope for the effectiveness of spectral methods of analysis [4].

This paper presents the results of the study of the acoustic noise of the Chevrolet Cruze engine (petrol, 120 hp, in-line, 4 cylinders). Signals were recorded using a voice recorder installed under the hood of the car near the engine cylinders (frequency range 200-7000 Hz, signal-to-noise ratio 37 dB), to eliminate the influence of the AGC of voice recorder on the signal strength determination, a generator was used, at the sound level of which normalization was performed.

The data was recorded for a variety of engine operating modes (city mode, highway, at various engine shaft speeds). Records for spectral analysis had a sampling frequency of 16,000 Hz, periodograms were built on the basis of 2-second realizations (during this time, mechanical details provided by the inertia of the stationarity of the spectral characteristics), energy spectra were calculated with the help of FFT (2048 points, Hamming window).



Figure 1 shows a typical periodogram of engine sounds while driving a car along the highway. To the left is the energy spectrum in conventional units (normalization to the maximum), on the right in a logarithmic scale.

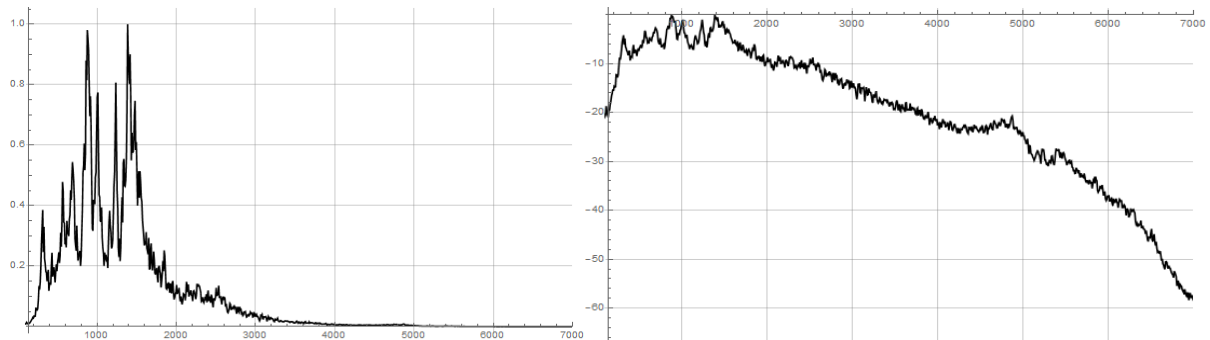


Figure 1. Typical energy spectrum of noise in linear and logarithmic scales.

The width of the spectrum depended on the engine speed of the crankshaft. Figure 2 shows the energy spectra at rotational speeds of 900 and 2300 rpm. On average, the spectrum width at a power level of 0.5 (3 dB) was 1 kHz (band 600-1600 Hz).

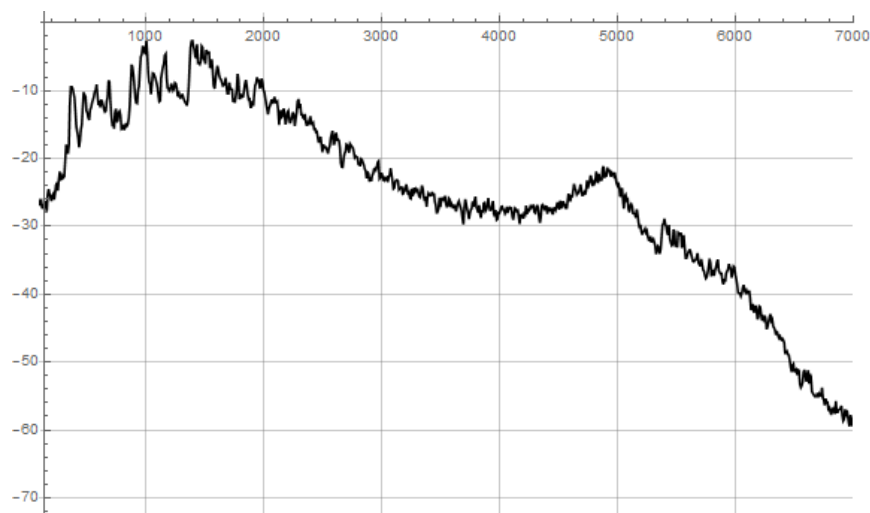


Figure 2. Dependence of the shape of the spectral density on the frequency of rotation of the motor shaft.

A characteristic feature of all spectra is the presence of a local maximum at a frequency of about 5000 Hz, which is clearly visible at a logarithmic scale on the sound power axis (Figure 3).

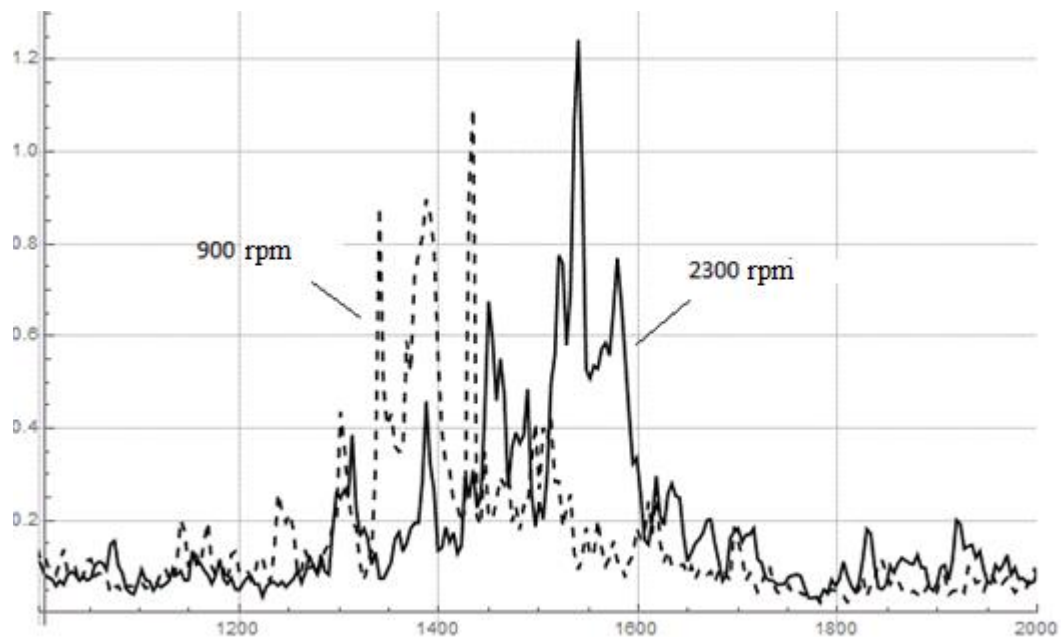


Figure 3. Energy spectrum of acoustic noise in a logarithmic scale.

To compare the sound in different modes of engine operation, a sound generator was installed at the power level under the hood. Figure 4 shows the periodograms at a motor speed of 2300 rpm and 900 rpm, normalized to the power of the sound generator (this procedure eliminated the effect of automatic adjustment of the recorder's gain). It can be seen from the figure that when the engine speed is increased, the sound power is greatly increased.

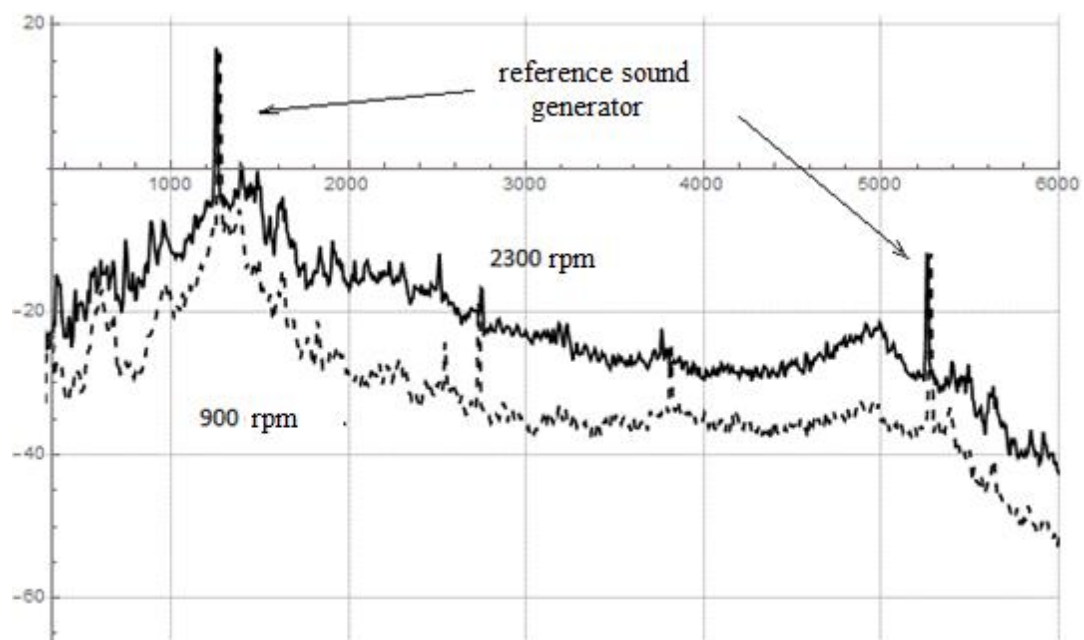


Figure 4. Normalized to the sound level of the reference oscillator periodograms.

In general, experimental data show that the main energy of the engine sound is concentrated rather in a narrow frequency range. Perhaps the main generation of sound is determined by the combustion processes of the fuel, mechanical oscillations of the pistons have too low frequency to generate the recorded sound, but they can modulate higher-frequency components and be observed as harmonics.

An additional study requires the identification of the nature of the local maximum at a frequency of 5000 Hz. Suitable parameters for generating such a high-frequency sound are detonation waves, hypothetical partial detonation of the fuel-air mixture can cause this component of the spectrum.

References

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