POWER AFFECTS TO THE SOUND PRESSURE OF A FOUR-STROKE ENGINE

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Abstract

The noise generated by the four-stroke S320 Andoria internal combustion engine is a complex field of study because the total sound pressure is the sum of the sound pressures produced by each engine component. The noise level and sound frequency of diesel engines used in agricultural machinery are highly dependent on fuel combustion. The standard diesel fuel conforming to EN 590 was used in the tests. Sound pressure was measured with the Bruel & Kjear equipment. Investigations show the dynamics of the dynamic parameters of the four-stroke engine, which must be evaluated when operating agricultural machinery. Experimental research of power influence on sound pressure of four-stroke diesel engine was performed. The dependence of the sound pressure level on the variation of the motor power was determined. Studies have shown that as the engine power increases from 2.63 kW to 9.48 kW, the sound pressure standard deviation increases by about 0.041 Pa.

Keywords: S320 Andoria internal combustion engine; sound pressure; engine power

1. Introduction

There are several sources of noise in the industrial and agricultural environment. Machines with rotating or high speed motors are the most typical sound sources that are very closely related to comfort requirements [3, 5, 7, 18, 21]. Because the sound pressure level of the machines has a direct impact on the biological and psychological systems of the operator and the surrounding users, and the sound of the machine is a very important criterion when choosing a vehicle. In addition, the sound signal can be analysed to see how the machines work. The noise level and sound frequency of diesel engines are highly dependent on fuel combustion [13, 16, 17]. The development of sound pressure in diesel engines is influenced by the spontaneous ignition of fuel. Therefore, the ability to distinguish between combustion noise and total noise would be a major challenge. This

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would allow engineers to associate engine sound pressure parameters with combustion parameters [19]. Diesel engine noise propagation in space causes discomfort to drivers and pedestrians. The main sources of noise generation in a diesel engine are the exhaust system, mechanical processes such as valve movement and the combustion process that dominates [2, 15].

Sound pressure characteristics have been evaluated in a small number of articles. Investigations in engine performance analysis relate to operators' psychomotor abilities to recognize motor failure by sound [12]. Sound parameters were studied using exhaust system sounds to determine engine performance [14]. The subjective assessment proposes the Integrated Satisfaction Index (ISI) as a criterion for noise quality differentiation, while objectively describing and analysing the noise quality of a diesel engine [9]. More extensive research is done on the analysis of detonation noise, which is masked by the harmonic oscillations of other engine parts, but the noise assessment itself has been conducted subjectively with volunteers. They rated the noise level by scores [20]. The equipment used for the sound analysis of the motor is the equipment used for measuring the noise level (microphones) and for its analysis the proposed combined method of localization of binaural sound and methods of separation of blind sources [19]. Modification of the engine block to reduce noise is used in research. But it brings big financial outlays to engine improvements [10]. Psychoacoustic models are also used and derived to describe the perceived sound quality of digitally calculated motor sounds [4]. Opposite frequency harmonic signals are used as a method of noise reduction in motors [11].

In this work, experimental tests were performed on a four-cylinder diesel engine to investigate noise propagation at different engine loads.

2. Experimental equipment and methods

This study used a four-stroke S320 Andoria diesel engine. The main characteristics of this engine is presented in Table 1. The experimental stand is shown in Figure 1. It consists of internal combustion engine S320 Andoria, fuelled standard diesel fuel conforming to EN 590 (position 1 in Figure 1) with CELMA Type 2Sf200 L6/4A electric starter-generator, the measurement equipment Bruel & Kjaer (position 2 in Figure 1) and microphone (position 3 in Figure 1).

Tab. 1. S320 Andoria engine characteristics [1]

Parameters	Meaning
No. of cylinders	1
Bore diameter (mm)	120
Piston stroke (mm)	160
Displacement (cm3)	1810
Compression ratio	17
Rated power (kW/HP)	13.2/18
Rated speed (rpm)	1500
Peak torque (Nm)	84.4
Peak torque speed (rpm)	1200
Minimum idle speed (rpm)	800
Spec. fuel cons. at rated power (g/kWh) ± 5%	258
Oil cons. referred to rated power (g/kWh)	1
Lubrication	Pressure and splash
Engine oil	Grade CB/SC SAE 15W40

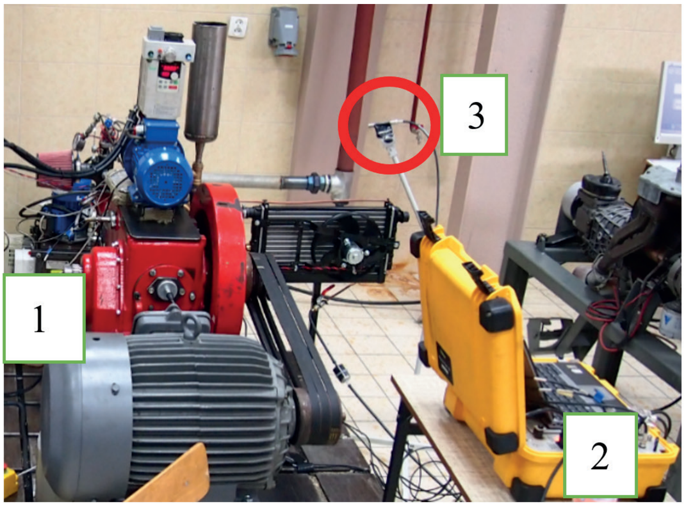

Fig. 1. Engine sound pressure measurement stand: 1 - Andoria Diesel engine S320 with CELMA Type 2Sf200 L6/4A electric starter-generator; 2 – Bruel & Kjaer sound record equipment; 3 - microphone

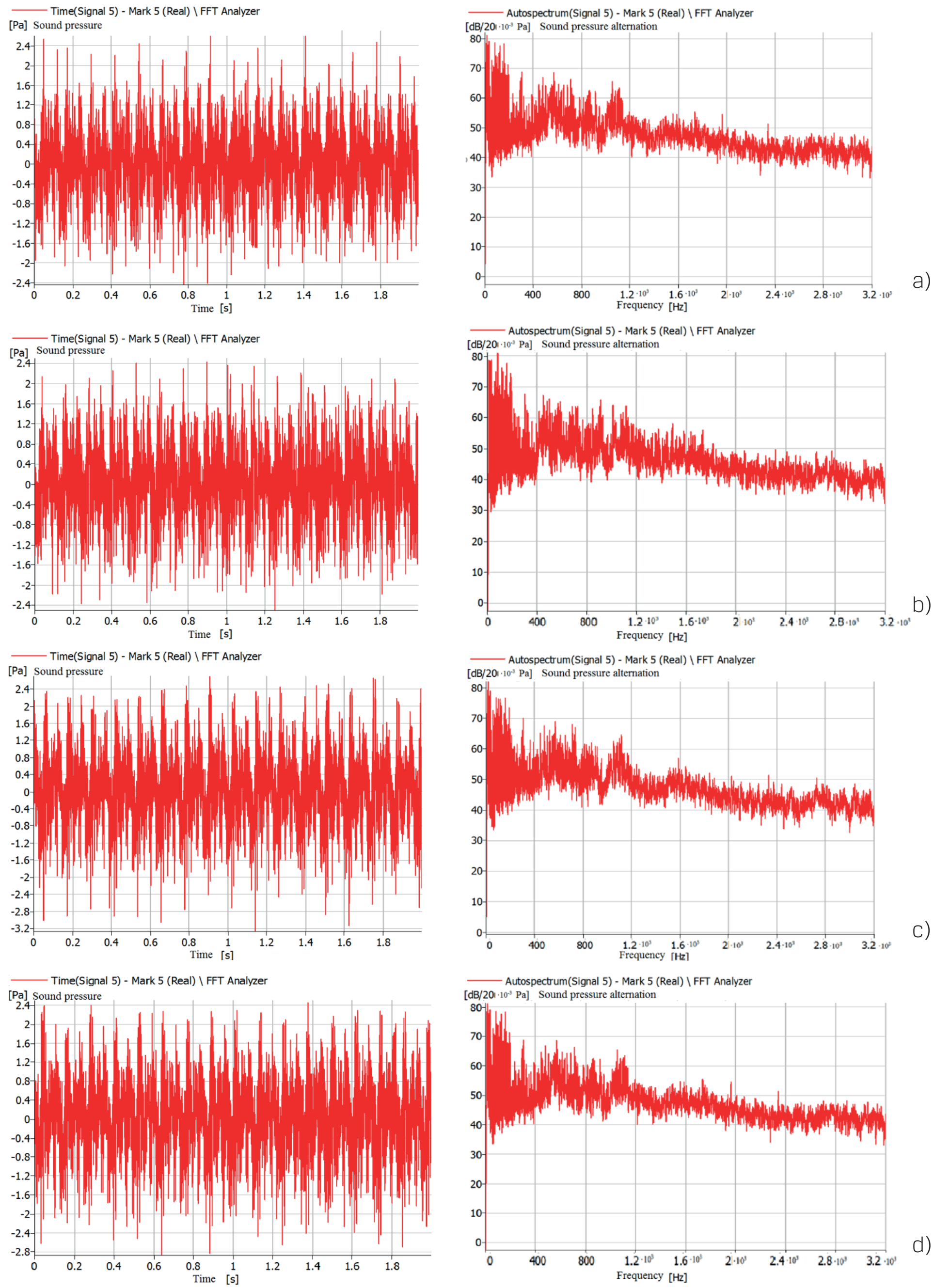

Fig. 2. The graphs of sound pressure and its spectral density were varied with power under different operating conditions: a – 2.63 kW; b – 4.8 kW; c – 6.56 kW; d – 9.48 kW

Sound pressure was measured during the study using Bruel & Kjaer equipment. The description of this equipment you can find in the other author's works [8]. The measurements carried out allow to evaluate the variation of the sound pressure depending on the power of the engine used in agricultural machinery, and the performed studies show the regularities that have to be evaluated during the operation of agricultural machinery. Because the noise level and sound frequency of diesel engines used in agricultural machinery are highly dependent on fuel combustion 2.63 kW, 4.8 kW, 6.56 kW and 9.48 kW were selected for testing according to Jukneleviĉius's work [6].

For each experiment, sound pressure data were collected up to 3.2 kHz and the time interval of recording was 2 seconds. Experimental studies have evaluated the variation of sound pressure at different engine loads.

3. Research results

The characteristics of sound pressure and its spectrum are presented in Figure 2 and Figure 3. Figure 2 the results of the sound pressure measurements for different operating conditions are presented and the power was changed (2.63 kW, 4.8 kW, 6.56 kW and 9.48 kW).

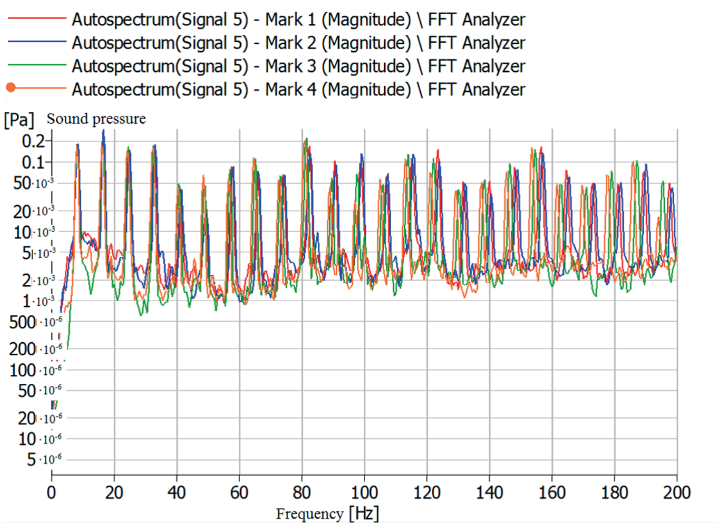

Fig. 3. Graph of sound pressure spectral density under different operating conditions (variable power 2.63 kW, 4.8 kW, 6.56 kW and 9.48 kW) with frequency range up to 200 Hz

The analysis of the spectral density graphs (Figure 2, Figure 3) shows the dominant motor frequency of 12.5 Hz and the occurrence of iterative frequencies. The spectral density graphs showed that the decrease in the obtained acceleration values was primarily due to the lower energy transmitted through the engine pistons transformed from the chemical fuel energy.

The left hand side shows the advantage of the sound pressure method over the current time series by analyzing Figure 2. Significantly more informative data is obtained, allowing frequency-dependent identification of engine performance over a standard time series where it is very difficult to identify differences. It can be observed (Figure 2 (a) and (b)) that, based on the time series, the pressure variation of the stall was very similar and ranged from 2.4 Pa to (-2.4) Pa. There was little difference in the sound pressure with respect to the frequency characteristics (right-hand sides of parts a and b in Figure 2), but this difference was noticeable in the amplitude decrease from 8 kHz to 3.2 kHz. With the increase in engine power (Figure 2 (c) and (d)), there was a noticeable increase in sound pressure of the lower dallies by 25% and 15%, respectively. Analyzing the dependencies of frequency characteristics on sound pressure density, similar tendencies became even more evident as in parts a and b of Figure 2.

Accordingly, Figure 3. a summary diagram of the spectral density of the sound pressure at different operating conditions (variable power 2.63 kW, 4.8 kW, 6.56 kW and 9.48 kW) is presented and frequency range up to 200 Hz is given. Figures: 2 and 3 are show of acceleration and spectral density. Figure 3 the spectral density of the sound pressure is colored as follows: red - engine power 2.63 kW; blue color - engine power 4.8 kW; green color - engine power 6.56 kW; orange - engine power 9.48 kW. In all cases, it is noticeable that increasing the genus increases the repetition of the amplitude.

The results of this study provide a broader range of research data for analyzing changes in sound pressure density, and allow comparisons of two research methods by time series and frequency. The latter method provides more insight into the operation of the engine under different engine loads, which allows expanding the possibilities of such research in the future.

4. Conclusions

These results allow contactless identification of changes in engine power based on sound pressure density using inexpensive research methods. The range of applications of these research methods is very wide and in the future the use of different fuels can identify changes in engine power, which was not done in this work, but could serve as a target for further research.

The obtained graphs show that the standard deviation sound pressure level is: about 0.663 Pa (standard deviation value for power 2.63 kW); about 0.700 Pa (standard deviation value for power 4.8 kW); about 0.745 Pa (standard deviation value for power of 6.56 kW); 0.786 Pa (standard deviation value for power of 9.48 kW).

The analysis of sound pressure spectral density graphs shows the dominant engine frequency of 12.5 Hz and the occurrence of iterative frequencies.

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