THE EFFECT OF ADDITION OF LPG AND CAMELINA OIL ESTERS ON NOISE AND VIBRATION IN A DUAL FUEL CI ENGINE

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Summary

With the development of internal combustion engines, engineers attempt to reduce the noise and vibration generated. Due to the high cost of fuel, are increasingly looking for new sources of power in order to reduce costs. In diesel engines, an increasingly popular method is the admixture of propane-butane. This follows because of the price of the fuel as well as to improve the efficiency of combustion. With the development of this type of dual fuel power seems to be a reasonable study of the effects of LPG to generate noise and vibration, as well as an attempt to evaluate the combustion process. The article describes preliminary studies on these phenomena example Yanmar L70 with a modified injection system of diesel and LPG in the gaseous phase. The paper presents the results of noise and vibration of dual fule engine using different shares of LPG and camelina oil esters.

Keywords: Diesel, LPG, dual fuel, sound and vibration.

WPŁYW DODATKU LPG ORAZ ESTRÓW LNIANKOWYCH NA EMISJĘ HAŁASU I DRGAŃ W DWUPALIWOWYM SILNIKU O ZAPŁONIE SAMOCZYNNYM

Streszczenie

Wraz z rozwojem silników spalinowych, inżynierowie podejmują próby redukcji emitowanego hałasu i generowanych drgań. Ze względu na wysokie koszty paliwa, coraz częściej poszukuje się nowych źródeł zasilania w celu obniżenia kosztów. W silnikach o zapłonie samoczynnym, coraz bardziej popularną metodą jest domieszka propan-butanu. Wynika to ze względu na cenę tego paliwa jak również na poprawę efektywności spalania. Wraz z rozwojem tego typu zasilania dwupaliwowego rozsądnym wydaje się być badanie wpływu dodatku LPG na emisję hałasu oraz generowanie drgań, jak również próba oceny procesu spalania. W artykule opisano wstępne badania dotyczące tych zjawisk na przykładzie silnika Yanmar L70 ze zmodyfikowanym układem zasilania oleju napędowego oraz instalacją LPG w fazie gazowej. Przedstawiono wyniki badań wibroakustycznych podczas pracy silnika pod obciążeniem dla różnych udziałów dawki LPG oraz podczas zamiany części oleju napędowego olejami estrowymi.

Słowa kluczowe: Diesel, LPG, dwupaliwowy, hałas i drgania.

1. INTRODUCTION

Together with the growing strictness of regulations on exhaust gases emission [1], the solutions are sought for that could comply with the requirements of such standards. One of the solutions seems to be employment of the bi-fuel supply systems for diesel engines. The addition of liquefied petroleum gas (LPG) to the diesel oil results in reduction of the harmful compounds emission; at the same time, for economic reasons, there has been rising interest in LPG gas fittings in compression-ignition engines observed. Gas fittings offered on the market allow for addition of approximately 30 % propane butane mix. This ratio results mainly from two reasons: because of the liability to the knocking combustion which takes place in bi-fuel supplied compression-ignition engines, and because of the higher exhaust gases temperature and higher combustion pressure. The result of the above phenomena can be the destructive impact on the combustion chamber's elements and on the exhaust system, as well as influence on noise emission and generated vibrations [7, 9]. In relation to the abovementioned problems, which can be encountered in this type of engine fuelling, the decision has been taken about starting the research on the influence the chosen control parameters can have on the compression-ignition engines, especially on the emitted noise and generated vibrations.

2. WORKBENCH TESTS

A workbench used during the test sessions (Fig. 1) was equipped with a compression-induced ignition engine type with a modified system of diesel oil fuelling and sequential gas injection fitting. Many researchers have explored the subject of dual-fuel diesel engines, mainly in terms of ecological[2, 3, 9]. It is difficult to find information on the effect of the addition of LPG to generated vibration and noise emission.

The tested engine was a one-cylinder, four-stroke Yanmar L70, with a compression ratio 20, air-cooled after a fuelling system modification. The original injectors system was replaced by a direct-inject dispensing system, which was installed in the 1.6 TDI VAG engine (high-pressure pump powered by an electric engine, a dispenser, a piezoelectric injector).

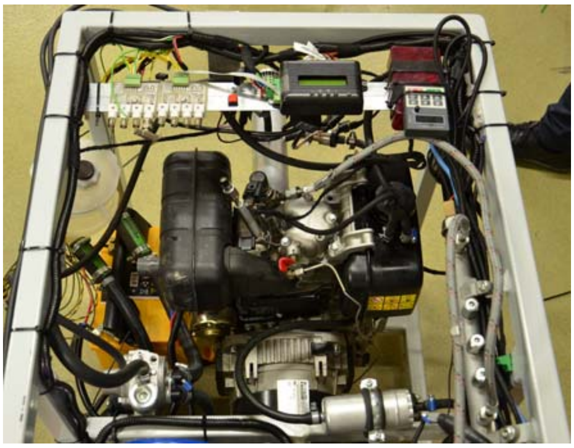

Fig. 1. Test stand with integrated modified engine

This workbench was prepared so that a wide spectrum of modification possibilities could be guaranteed, related to control parameters as well as easy introduction of changes in fuelling and loading systems. A programmable logic controller, designed as part of the Engineer's Thesis, has been used to bias-control the bi-fuel engine fittings. It has four analogue/digital inputs, four interrupt inputs, and five outputs with power degrees, including three capable of work in the PWM mode. This number of inputs and outputs is sufficient to bias-control the basic fittings of the common rail system and of the LPG injection. The control programme has been written in the C language. The controller allows for a change in the opening time of a piezoelectric injector and an LPG injector, which enables to influence the fuel proportion without difficulty. The controller also manages the CAN network which is used to send the controlling data from the LabVIEW environment [5, 6]. The most important data sent from the computer:

- injectors opening times;
- dividing the dose into the main and pilot doses together with the piezoelectric injector opening times;
- present injection pressure;
- injection advance angle (timing);
- maximal revolutions limitation;
- glow plug heating;
- LPG reducer heating.

All tests were performed under the constant load (about 70% of maximum power) , using an electric generator that powered electric device with constant power consumption. The rotational speed ranged from 2750-2850 rpm.

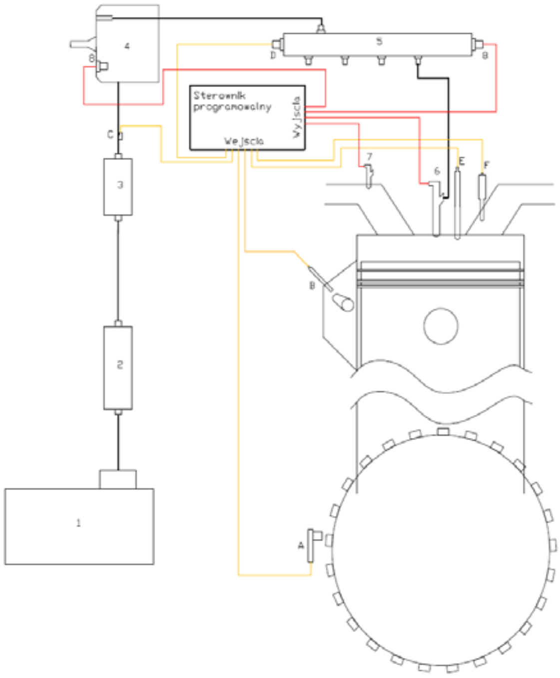

Fig. 2. Workbench diagram: 1-container, 2-electric pump, 3-fuel filter, 4-high pressure pump, 5-dispenser, 6-piezoelectric injector, 7-LPG injector, 8-fuel dose valve/pressure valve, A- crankshaft position sensor, B-stroke recognition sensor, C-fuel temperature sensor, D-fuel pressure sensor, E- glow plug with a cylinder pressure sensor, F- EGT sensor

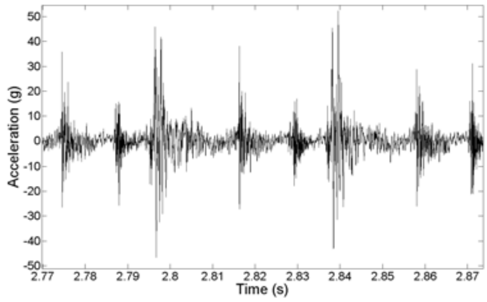

Fig. 3. Recorded single vibration signal

3. ANALYSES OF ACOUSTIC EMISSION AND GENERATED VIBRATIONS

There has been a series of tests conducted, related to the influence of such parameters as injection timing, fuel composition proportion (diesel oil/LPG) as well as the addition of Camelina (*Camelina sativa*) esters on the bi-fuel engine performance, especially on generated vibrations and noise. More information about this fuel has been presented in work [4]. Doses were selected so that the calorific contribution corresponded with the basic diesel oil dose. The fuels were mixed in different proportions:

- diesel oil was mixed with the Camelina sativa ester oil in proportion 70÷30 percent;
- diesel oil was mixed with LPG in proportion 80÷20 or 90÷10 percent;
- the mixture of diesel oil and esters in proportion of 70÷30 percent was mixed with 10 or 20 % LPG.

These proportion due to the fact that during the preliminary studies tried to work on the safe dose LPG for tested engine. In the future, researches focus on bigger one shares of LPG.

Vibrations were measured on the tested cylinder head with the acceleration sensor. This sensor was placed on the head of the tested engine. Noise was also measured in proximity of the cylinder head, from the side of the exhaust system. The acoustic pressure sensor was applied to perform this activity.

In the research used LabVIEW environment for recording signals from the acoustic pressure sensors (B & K type 4958) and the 3-axis acceleration sensors (B & K type 4504). The signal sampled at a frequency 51,2kHz and each measurement last 10 seconds. Data Acquisition is used to register the NI 9234. Engine was indicated using glow plug PSG, which is integrated piezo-resistive sensor.

In the first place the chosen amplitudinous spectra of engine vibrations have been shown. Subsequently, the collected test results have been processed and the amplitudinous spectra have been generated picturing the acceleration amplitudes. The diagrams depict the spectra in function of frequency for different fuels or for different injection advance angles (injection timing). The first test was carried out because of the planned increase of the esters proportion in sold fuels over the next few years, meaning that esters will be among ingredients of the mixture used in bi-fuel supply system.

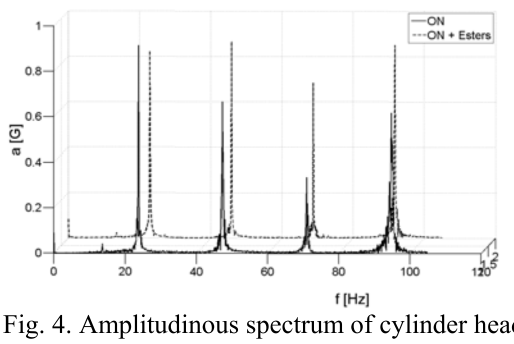

Fig. 4. Amplitudinous spectrum of cylinder head vibrations for diesel oil with 30% proportion of Camelina sativa esters

As can be seen in the presented diagram (Fig. 2), the addition of esters results in the increase of cylinder head vibrations amplitude, especially for the frequency corresponding with the engine's rotational speed.

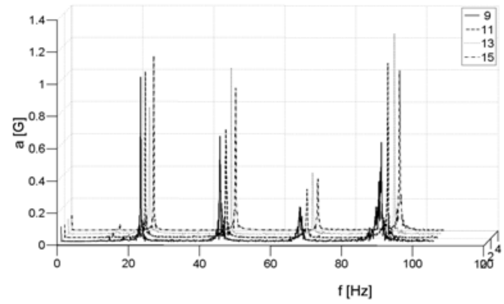

Fig. 5. Amplitudinous spectrum of cylinder head vibrations for diesel oil with different angles of fuel injection advance [9°,11°,13°,15°]

During the consecutive stage of the research the influence of change in injection advance angle (timing) on generated vibrations has been analysed. As shown in Figure 3, the injection advance angle (timing) increase leads to growth of generated vibrations. In the case of injection advance angle (timing) being equal to 13°, in spite of the smaller value of amplitude of the first harmonic, in the subsequent harmonics the growth of amplitude can still be observed. The conducted research proves that the later the fuel injection takes place, the lower the generated vibrations. On the other hand, the pressure in the combustion chamber (discussed in detail further in this article) was measured in the course of the research, and it dropped alongside the delayed fuel injection. At the same time, during the tests there have been different proportions of fuel supply used, in order to attempt optimalisation of fuel composition and parameters controlling the engine performance. The diagrams (4 and 5) illustrate how addition of both: esters and LPG results in the increase of vibration amplitude of the tested engine. The proof has been obtained by measuring the acoustic pressure in proximity of cylinder head. The amplitudinous spectra shown in Fig. 6, 7, and 8 illustrate the above. The diagram (Fig. 7 and 8) depicts the influence of the LPG addition on the noise emission growth. The situation is similar when a part of diesel oil is replaced by esters (Fig. 6 and 7). This can be clearly noticed at two first harmonic frequencies corresponding to rotational speed and explosions of the air-fuel mixture.

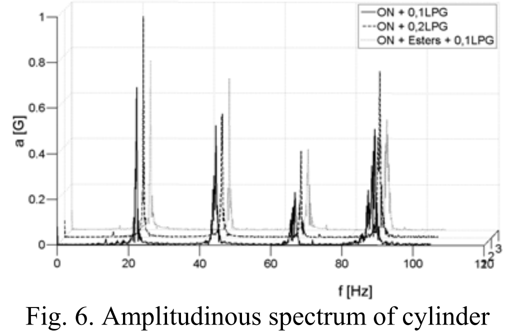

Fig. 6. Amplitudinous spectrum of cylinder head vibrations for diesel oil and for mixture of diesel oil and esters and LPG

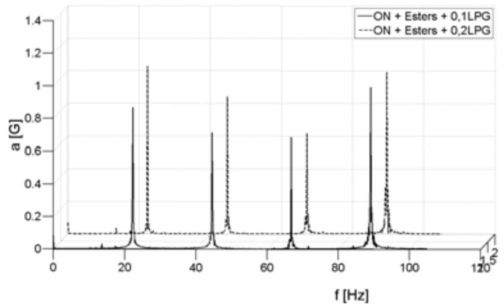

Fig. 7. Amplitudinous spectrum of cylinder head vibrations with addition of LPG to diesel and ester oil mixture

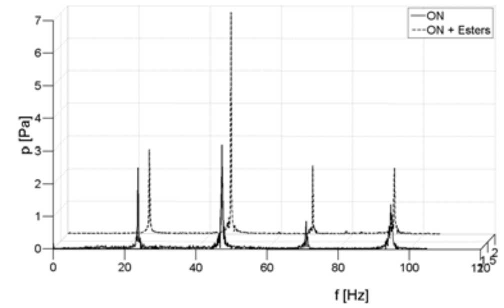

Fig. 8. Amplitudinous spectrum of acoustic pressure measured in proximity of cylinder head with addition of ester oil

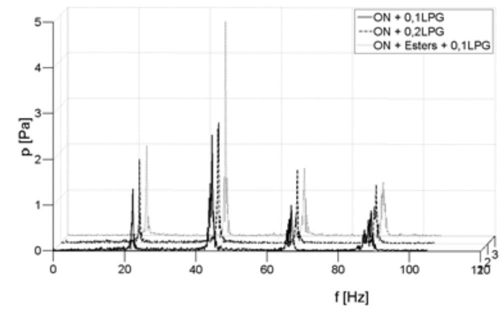

Fig. 9. Amplitudinous spectrum of acoustic pressure measured in proximity of cylinder head for diesel oil and for mixture of diesel oil and esters and LPG

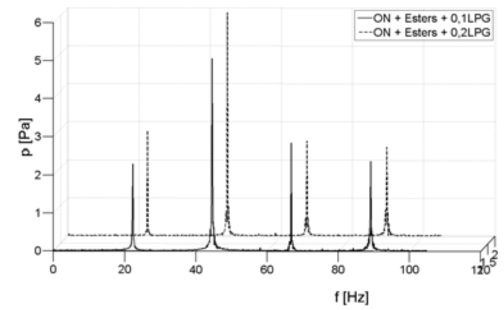

Fig. 10. Amplitudinous spectrum of acoustic pressure measured in proximity of cylinder head with addition of LPG to mixture of diesel oil and ester oil with LPG

In the course of the discussed tests the pressure measurements were taking place in the combustion chamber using a marketable glow plug with a pressure sensor (PSG). This is a glow plug equipped with a piezoresistive pressure sensor taking measurements of pressure values inside the combustion chamber. The record of pressure flow was coordinated with the crankshaft position record, from the crown gear consisting of 97 teeth. These diagrams have been averaged out from 200 cycles. Due to this fact the combustion flow efficiency can be compared, at the same energetic value of fuel delivered.

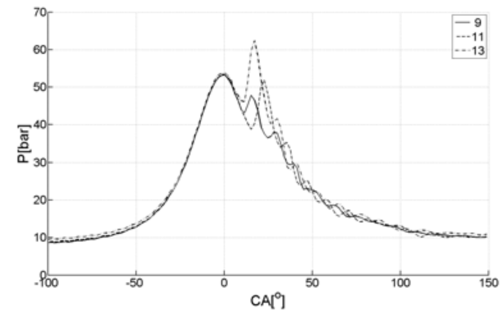

Fig. 11. Pressure flow of diesel oil combustion for different injection advance angles (timing values)

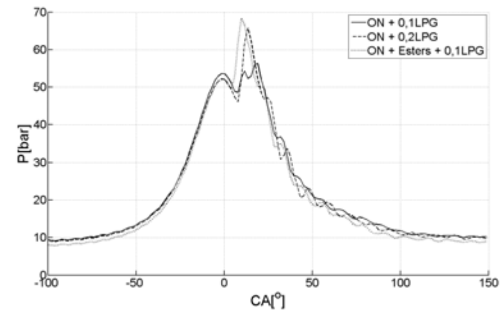

Fig. 12. Pressure flow of diesel oil combustion and diesel oil mixed with esters and LPG

The above diagrams (Fig. 9 and 10) illustrate that both: the earlier timing (angle of injection advance) and the addition of LPG cause the increasing combustion pressure. The maximal combustion pressure is much greater which directly influences the generated noise and vibrations. The addition of esters on the combustion of air-fuel mixture will be described in another article. It is worth mentioning that a marketable plug with pressure sensor allows for generating diagrams of high resolution that enable comparative analysis.

4. CONCLUSIONS

Analysis of the collected results makes it possible to state it is clearly visible that acceleration of the injection advance angle leads to a greater noise and vibration production with the simultaneous combustion pressure increase. The influence of the esters' addition causes increase of noise and vibrations with the similar efficiency of fuel combustion process (Fig. 2-8). The influence of LPG addition results in increasing combustion process efficiency with the simultaneous increase of vibrations and noise. Properly adjusting the parameters such as injection timing, fuel dose, you can try to optimize the process in terms of reducing vibration and noise while maintaining the highest efficiency of the combustion process.

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