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Selected aspects of dual-fuelling of the Perkins 1104D-E44TA engine with natural gas and Diesel fuel

Wybrane aspekty dwupaliwowego zasilania silnika Perkins 1104D-E44TA gazem ziemnym i olejem napędowym

Abstract

The paper presents selected test results of the PERKINS 1104D-E44TA engine, adjusted to being dual-fuelled with compressed natural gas and Diesel fuel. The tests were carried out with maximum possible dosing of natural gas and then with lowering its dosing by approximately half. The obtained test results were compared with the results of tests carried out when the engine was powered with Diesel fuel only.

Keywords: internal combustion engines, engine fuels, natural gas, dual-fuel power supply

Streszczenie

W artykule przedstawiono wybrane wyniki badań silnika PERKINS 1104D-E44TA przystosowanego do zasilania dwupaliwowego sprężonym gazem ziemnym i olejem napędowym. Badania przeprowadzono przy maksymalnym możliwym dawkowaniu paliwa gazowego i po jego zmniejszeniu o około połowę. Otrzymane wyniki badań porównano z wynikami uzyskanymi przy zasilaniu silnika olejem napędowym.

Słowa kluczowe: silniki spalinowe, paliwa silnikowe, gaz ziemny, zasilanie dwupaliwowe

1. Introduction

Liquid fuels, gasoline and Diesel fuels obtained from oil are conventional fuels for powering piston combustion engines. Their characteristics determine constructional properties of engines. Using alternative fuels for combustion engines is possible, but it usually requires adopting engines for such fuels. An engine powered with alternative fuel should have similar operation properties but less harmful impact upon natural environment. With regard to Diesel engines, alternative fuels may also include vegetable oil esters [1, 2, 3]. Using esters requires no constructional modifications in the engine or other feeding system. It is possible because of similar physical and chemical properties of both vegetable oil esters and Diesel fuels, obtained from oil. Also, gas fuels are an interesting alternative for powering combustion engines. However, using such fuels demands the employment of completely different feeding systems than those for liquid fuels. Currently, a bi-fuelling system is being employed, that is, powering engine with either liquid or gas fuel. It is a universal and commonly applied solution. Diesel engines may be adopted for dual-fuelling, which means powering the engine with both gas and liquid fuel at the same time. The issue of powering combustion engines with alternative fuels is currently the scope of extensive research and numerous tests.

2. Natural gas as fuel in transportation

Natural gas is a source of energy which may allow for diminishing harmful impact upon natural environment, when compared to oil and coal, due to the fact that natural gas is mainly composed of methane – one of the simplest coal-hydrogen compounds (up to 85÷99% content) [4]. Apart from methane, natural gas contains other volatile hydrocarbons, such as propane, butane, pentane, hexane, and others [5], as well as slight amounts of inert gases and noble gases, such as nitrogen, argon or helium. Natural gas may also contain heavier hydrocarbons, compounds of sulphur, water and slight amounts of carbon dioxide. The properties of natural gas are determined by the properties of methane.

Natural gas is an organic fossil fuel, formed as a result of anaerobic decomposition of organic substances in deep layers of soil [6]. Deposits of natural gas may occur independently or with deposits of oil and coal. It may be used in a compressed (Compressed Natural Gas – CNG) or liquefied form (Liquefied Natural Gas – LNG). The technology of using the compressed form (CNG) for powering combustion engines is explored better, but efforts are being currently made to develop the technology of utilising the liquefied form (LNG). The possibilities of using natural gas for powering combustion engines are widely discussed in literature [7, 8, 9]. Using such fuels, however, requires designing and installing feedings systems which are adequate for the properties of gas fuels.

The European Union prioritises the increase of alternative fuels compared with petrol and Diesel fuels [10, 11, 12]. This means that the interest in natural fuel as an energy source for powering piston combustion engines will be growing.

3. Test stand and tested item

A Perkins 1104D-E44TA Diesel engine with direct fuel injection system was the tested item. It is equipped with a Common Rail injection system that employs electromagnetic injectors. The feeding system and the entire engine are controlled by the electronic controlling unit. The Perkins 1104D-E44TA engine installed on the engine testing station was adopted for being dual-fuelled with Diesel fuel and compressed natural gas (Diesel+CNG). The engine may be powered with both fuels at the same time or with Diesel fuel only. A flowchart of the testing station with the Perkins 1104D-E44TA engine is presented in Figure 1.

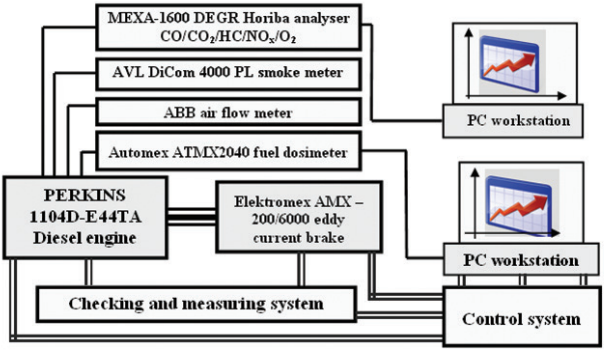

Fig. 1. Testing station flowchart

4. Selected test results

During the tests, the PERKINS 1104D-E44TA Diesel engine was operating under load characteristic for the rotational speed of the crankshaft of 1800 rpm and it was dual-fuelled with natural gas and Diesel fuel. The tests were carried out with maximum natural gas dosage (Diesel+CNG), specified during the calibration of natural gas feeding system, and with natural gas dosage reduced by approximately half (Diesel+1/2CNG). In addition, one test included an engine powered with Diesel fuel only. Figure 2 presents energy shares of natural gas in the entire amount of energy supplied into the engine cylinders with maximum natural gas dosing (Diesel+CNG) and with natural gas dosing reduced by half (Diesel+1/2CNG). Figures 3 and 4 present a comparison of the hourly fuel consumption (FC) and brake specific fuel consumption (BSFC) of the Perkins 1104D-E44TA engine, powered with Diesel fuel only and dual-fuelled with Diesel fuel and natural gas with maximum (Diesel+CNG) and reduced (Diesel+1/2CNG).

Figures 5, 6, 7, 8 and 9 present a comparison of the concentration levels of the carbon monoxide (CO), carbon dioxide (CO_2), total hydrocarbons content (THC) in and smokiness of exhaust fumes of the Perkins 1104D-E44TA engine, powered with Diesel fuel and dual-fuelled with Diesel fuel and compressed natural gas, with maximum (Diesel+CNG) and reduced (Diesel+1/2CNG) natural gas dosing.

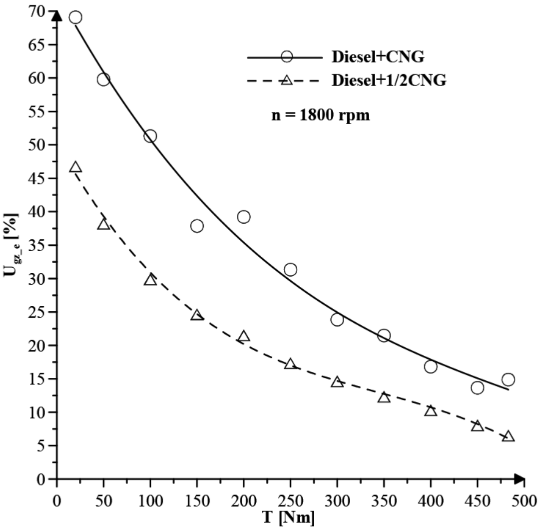

Fig. 2. The energy share of natural gas (U_{eCNG}) in total energy amount supplied into the cylinders of the Perkins 1104D-E44TA engine, dual-fuelled with natural gas and Diesel fuel with maximum (Diesel+CNG) and reduced (Diesel+1/2CNG) dosing

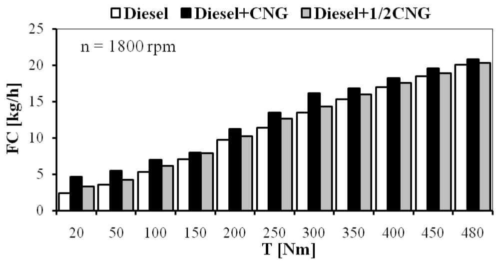

Fig. 3. Comparing the hourly fuel consumption (FC) of the Perkins 1104D-E44TA engine, powered with Diesel fuel only and dual-fuelled

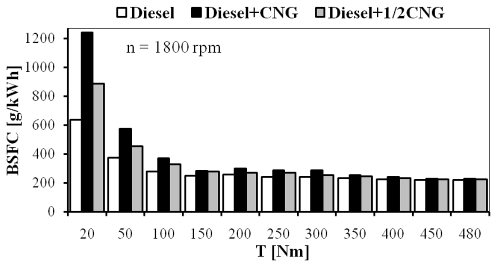

Fig. 4. Comparing brake specific fuel consumption (BSFC) of the Perkins 1104D-E44TA engine, powered with Diesel fuel and dual-fuelled

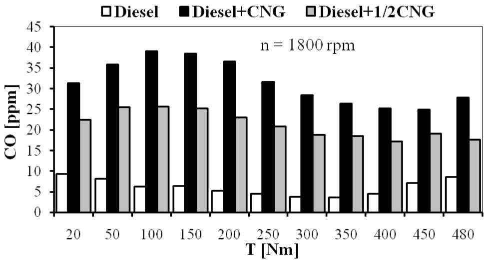

Fig. 5. Comparison of the concentration levels of carbon monoxide (CO) in the exhaust fumes of the Perkins 1104D-E44TA engine, powered with Diesel fuel only and dual-fuelled

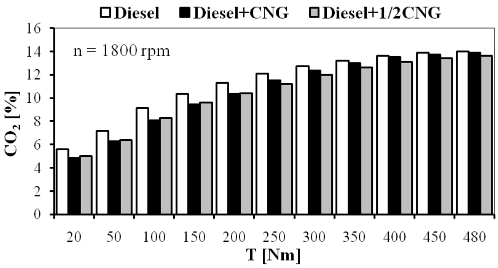

Fig. 6. Comparison of the concentration levels of Carbon dioxide (CO2) in the exhaust fumes of the Perkins 1104D-E44TA engine, powered with Diesel fuel only and dual-fuelled

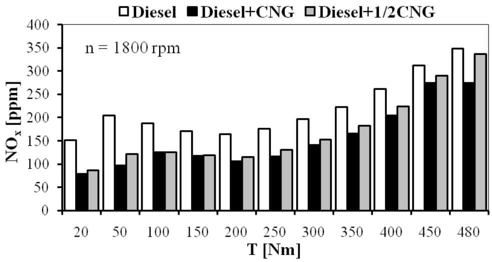

Fig. 7. Comparison of the concentration levels of nitric oxides (NO_x) in the exhaust fumes of the Perkins 1104D-E44TA engine, powered with Diesel fuel only and dual-fuelled

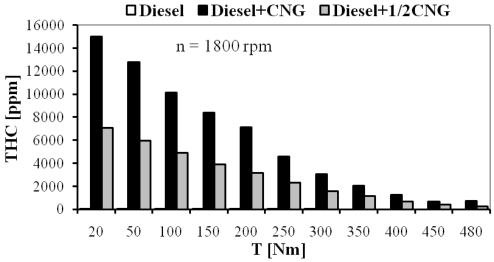

Fig. 8. Comparison of the concentration levels of total hydrocarbons (THC) in the exhaust fumes of the Perkins 1104D-E44TA engine, powered with Diesel fuel only and dual-fuelled

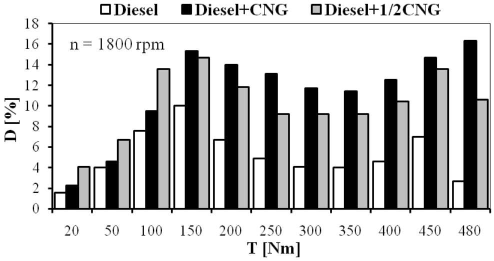

Fig. 9. Comparison smokiness of the exhaust gases (D) of the Perkins 1104D-E44TA engine, powered with Diesel fuel only and dual-fuelled

3. Summary

With the Perkins 1104D-E44TA Diesel engine dual-fuelled with natural gas and Diesel fuel, and with its operation under the load characteristic, the hourly and specific fuel consumption was higher than with the engine powered with Diesel fuel only. With reduced natural gas dosing, the hourly and specific fuel consumption were lower than with maximum natural gas dosing.

The reduction of the content of nitric oxides and carbon dioxide in the engine's exhaust fumes was a positive outcome of using natural gas for powering the engine. The concentration levels in each measurement point were lower when compared to the engine being powered with Diesel fuel only. With maximum natural gas dosing, the concentration levels of nitric oxides in exhaust gases were lower than with reduced natural gas dosing.

When the Perkins 1104D-E44TA engine was dual-fuelled with natural gas and Diesel fuel, it resulted in higher concentration level of carbon monoxide as well as a multiple increase of total hydrocarbons in the exhaust fumes. It is most likely caused by incomplete combustion of methane as well as deteriorated conditions of the combusting process of Diesel fuel in the dual-fuelled engine. Also, a higher concentration of methane in exhaust gases may be caused by its outflow with the air through the exhaust valves during the load exchange process in a cylinder.

When the engine was dual-fuelled with natural gas and Diesel fuel, a significant reduction of natural gas dosing resulted in lower concentration levels of carbon monoxide, hydrocarbons as well as smokiness of exhaust fumes compared with the maximum natural gas dosing. However, these concentrations and smokiness are still considerably higher than in the exhaust fumes of the engine powered with Diesel fuel only, as adopted by the manufacturer.

In order to reduce concentration levels of carbon monoxide and hydrocarbons in the exhaust fumes of a dual-fuelled engine, as well as their smokiness, it is necessary to modify the air-fuel mixture content as well as the course of the combustion process, mainly by means of changing parameters of the process of injecting Diesel fuel into cylinders.

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